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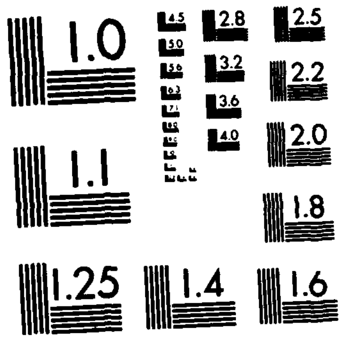

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WORK BREAKDOWN STRUCTURE FOR MANAGEMENT CONTROL OF EXPLORATORY DEVELOPMENT RESEARCH

Arthur D. Mills, Jr. Captain, USAF

LSSR 21-83

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

WORK BREAKDOWN STRUCTURE
FOR
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MIL-STD-881A establishes requirements and guidance on the preparation and uses of a WBS that is applied to, and geared for, the latter stages of RDT&E and during the production phase of major weapon systems. However, little guidance is provided on developing a WBS for Exploratory Development Research. The primary objective of this thesis was to develop a WBS for Exploratory Development Research. The objective was achieved by interviewing project engineers at AFWAL. The interview questions were divided into four categories: (1) Demographic data on the project engineers, (2) Characteristics of Exploratory Development Research, (3) Control structures currently used, and (4) Process and primary factors used to develop a SOW. Exploratory Development Research deals with the development and demonstration of a concept. The project engineers interviewed uses a Phase/Task structure to organize their projects. The phases consist primarily of: (1) Conception, (2) Preliminary and detail design, (3) Fabrication, and (4) Test & Evaluation. The detailed tasks under each phase are project specific. It is recommended that a level three WBS be used on Exploratory Development Research projects. The first level represents the total research project. The phases listed above make up the second level, and the detailed tasks under each phase compose level three.

LSSR 21-83

WORK BREAKDOWN STRUCTURE

FOR

MANAGEMENT CONTROL

OF

EXPLORATORY DEVELOPMENT RESEARCH

A THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirement for the

Degree of Master of Science in Systems Management

By

Arthur D. Mills Jr., BS
Captain, USAF

September 1983

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This thesis, written by

Captain Arthur D. Mills Jr.

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS MANAGEMENT

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CHAPTER 1

INTRODUCTION

Background

Between 25-30% of all scientists and engineers who influence research and development in the United States are employed by the Department of Defense (10:97). In addition, "over half of the approximately $40 billion spent in the United States each year on research and development comes from the federal government. Of this, national defense accounts for more than half /10:97/."

Research and development projects within the Department of Defense are initiated by the users in the field, scientists outside the Department of Defense as well as scientists within the Department of Defense. The basic purposes behind this research and development are (17:350; 27:18):

1. Development of new weapon systems to counter new threats.

2. Development of new weapon systems to counter existing threats.

3. Development of new uses for existing weapon systems.

4. Improvement in the quality of existing weapon systems.

5. Reduction of costs for supporting an existing weapon system.

6. Elimination of difficulties associated with the production or use of a weapon system.

A research project is initiated to accomplish one of the above purposes and can be viewed as a formal approach to achieving that purpose. The research project may be simple and require only one engineer, a few thousand dollars and a couple of months to accomplish; or it might be complex and require many people spanning several functions, at a cost of millions of dollars and spanning several years (27:231). "The objective of a project can be to develop hardware, to verify by testing, to carry out feasibility studies, or to investigate technical problems, among other aims. The project can solve a narrow problem or advance the state of the art. It can involve many or few knowns or unknowns, constant or variable, or combination of these [27:231]."

To achieve the objective of any research project, the basic steps of research and development must be performed. In addition, several iterations of each step may be required before a final weapon system is designed and put into production. The basic research and development steps are (17:357):

1. Thinking and visualization
2. Accumulation of information
3. Development of conceptual alternatives
4. Engineering exploration or feasibility
5. Reference design
6. Analytical investigation
7. Specification, construction, and test of materials, components, breadboards, and mock-ups

8. Drawings and initial engineering specifications
9. Construction of developmental models
10. Test of development models
11. Drawing and specifications of prototypes
12. Construction of prototypes
13. Test of prototypes
14. Construction of field test models
15. Field test
16. Final production design
17. Modification of design due to user or production problems.

Research and development has a higher degree of cost, schedule, and performance risk than does production. This is due to the following (14:3):

a) Research and development have many unknowns,

b) Research and development have little historical cost, schedule and technical data, and

c) The tasks and subtasks of research and development consist primarily of design and testing.

To track these inherent risks in research and development, proper management control must be exercised by the project engineer. However, "Control and responsive action are often difficult in R&D because assessments of progress are generally inaccurate. The intangible nature of work makes the appraisal of accomplishment in relation to dollar and time expenditures subjective /27:310-311/." Roman (27:362-363) goes on to say:

> Control involves the correlation of functional activities in an integrated reporting system which is accurate, objective, fast, and action directed. To be effective, control must give management early warning of variance from plans. If these are detected quickly enough, corrective action can be taken before resources have been over-expended to the point of impairing program objectives. Essentially, control includes the assessment and inter-

relating of these critical factors, examined in total perspectives; (1) actual performance compared with planned. (2) The schedule of accomplishment, and (3) expendiures in relation to accomplishment.

To insure that cost, schedule, and performance data recieved from the contractor on major government contracts meet the needs of project managers, the Department of Defense (DOD) adopted a set of control criteria which all major DOD contractors' management systems must meet. These criteria are discussed in detail in Air Force System Command Pamphlet 173-5 "Cost/Schedule Control Systems Criteria Joint Implementation Guide." The criteria deal with the contractor's procedure for organizing work and people, planning & budgeting, accounting, analysis of data, and revisions of plans.

The Work Breakdown Structure is the visible framework which ties the criteria together. MIL-STD-881A (32:2) defines a Work Breakdown Structure as:

> A product-oriented family tree composed of hardware, services and data which result from project engineering effort during the development and production of a defense material item, and which completely defines the project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.

A more in-depth discussion of a Work Breakdown Structure can be found in Chapter Three.

The Work Breakdown Structure facilitates planning, budgeting, monitoring, and controlling the progress of the work, resources allocation, cost estimates, expenditures, and technical performance. The Work Breakdown Structure, as a management tool, provides the common integrating thread be-

tween the Statement of Work, specifications, contract line items, contract end items, technical and management reports, and configuration control data (31:1).

MIL-STD-881A provides guidance on the preparation and use of Work Breakdown Structures. This standard establishes requirements and guidance that is applied to, and geared for, DOD acquistions that occur during the latter stages of research and development and during the production phase of major weapon systems. However, virtually no guidance is provided on establishing a Work Breakdown Structure for management control of research and development during the early stages of conceptualism and design. In addition, J. Flaherty (21:18) goes on to say:

> For cost analysis a weakness of the existing methods of development of the WBS is that the primary problems of weapon system cost estimating are in the early stages of system development and most of the current work in WBS is done during the latter stages of system development.

Problem Statement

Little guidance is provided to the laboratory project manager on the development of a Work Breakdown Structure for management control of Exploratory Development Research. Exploratory Development Research is further discussed in Chapter Three.

Objectives

The primary objective of this thesis is to develop a

model of a Work Breakdown Structure that can be used by laboratory project managers to control Exploratory Development Research. Secondary objectives are to:

1. Identify characteristics of Exploratory Development Research that influence management control.

2. Identify the type of structures currently being used by laboratory project managers to monitor and control Exploratory Development work units.

3. Identify the process a project manager goes through to develop the current structures used to monitor Exploratory Development work.

Hypothesis

The single hypothesis in this thesis is that a common structure for management control of Exploratory Development Research can be found within the laboratories and this common structure can be used to establish a model of a Work Breakdown Structure for use within the laboratories.

Format of Thesis

Chapter Two discusses the methodology used to collect and analyze the data required to determine an appropriate model to be used in developing a Work Breakdown Structure for Exploratory Development Research. The scope of the effort is discussed, which includes identifying sources for the literature review, the laboratories and government contrac-

tors participating in the study, data-gathering methods, the experience criteria established for selecting laboratory project managers to be interviewed, and the sample size. The interview questions and their relationship to the thesis objectives are discussed in detail. Finally, the chapter identifies limitations of the research effort.

In-depth discussion of Work Breakdown Structure is presented in Chapter Three. The chapter will cover the definition of a Work Breakdown Structure, the different types of Work Breakdown Structures, Air Force policy toward Work Breakdown Structures and the uses of Work Breakdown Structures. I will also briefly discuss the different research categories.

In Chapter Four the responses to the interview questions are analyzed and the results discussed. The full text of each response is presented in Appendix B, while summary tables of the responses are included in Chapter Four. The interview responses are related to the hypothesis and research questions.

In the final chapter, Chapter Five, major conclusions drawn from the research effort are presented. Based upon these conclusions a model Work Breakdown Structure is recommended for use by project engineers to monitor and control Exploratory Development Research projects. The Work Breakdown Structure presented is based upon the authors own opinion and recommendations provided by the project engineers interviewed.

CHAPTER 2

METHODOLOGY

This chapter discusses the methodology used to collect and analyze the data required to determine the appropriate model to be used in developing a Work Breakdown Structure for an Exploratory Development Research project. The chapter is broken into four parts: scope of effort; rational for the interview questions; data analysis; and the limitations of the research effort. The scope of the effort identifies sources for the literature review, laboratories and government contractors participating in the study, the research data gathering methods, the sample size, and the experience criteria established for selecting laboratory project managers to be interviewed.

Scope

A two-fold data collection method was used to determine the Work Breakdown Structure model for an Exploratory Development Research project. The first method was a structual personal interview of selected laboratory project managers and government contractors. The interview was designed to determine characteristics of Exploratory Development Research and to review current management control systems that could be used to develop an appropriate Work Breakdown

Structure for management control of research projects. The second data collection method was to review individual Statements of Work and identify the format structures used. From these formats develop a structure suitable for modeling a Work Breakdown Structure to be used in Exploratory Development Research.

The interview, consisting of the twelve questions found in Appendix A, was developed mainly to be used while interviewing laboratory project managers.

Two other methods were considered for data gathering prior to choosing the interview method. The first method was to investigate current Work Breakdown Structures and Statements of Work of Exploratory Development contracts and to analyze them for commonality. This commonality would then be used to develop a model Work Breakdown Structure for Exploratory Development contracts. This method was rejected for two reasons. First, after reviewing several project case files it was discovered that none of the contracts had a formal Work Breakdown Structure. Secondly, it was decided that only reviewing the Statements of Work there would be insufficient guidance to determine the process the engineer went through while developing a Statement of Work.

The second method considered was the use of a questionnaire for data gathering. Two types of questionnaires were considered. The first type required respondents to choose between several alternatives; the second type requi-

red the respondent to write-in their own responses. The prime reason for rejecting the first type was due to its inherent lack of flexibility. Due to the nature of the subject for this research, the project manager, for lack of a suitable choice, could be forced into choosing an alternative that did not apply. The second type was ruled-out because of the time constraints faced by most project managers. Also, due to the nature of questionnaires they would not have encouraged an open exchange of ideas.

Therefore, the interview method was chosen as the most acceptable method of data collection. It did not force the program manager to choose between alternatives and allowed the researcher to concentrate on those areas where the program manager was able to add the most insight. In addition to the interviews, individual Statements of Work for Exploratory Development contracts were reviewed to determine a suitable Work Breakdown Structure model. Access to these Statements of Work were provided by the individual procurement offices for each laboratory.

The laboratories selected for this research were the Air Force Wright Aeronautical Laboratories, consisting of the Avionics Laboratory, Aero Propulsion Laboratory, Flight Dynamics Laboratory and Materials Laboratory, all are located at Wright-Patterson Air Force Base, Ohio. The laboratories were chosen primarily on the basis of their work in the Exploratory Development field and their proximity to the Air

Force Institute of Technology. The government contractors were General Electric, located at Evandale, Ohio; and Rockwell International, located at Columbus, Ohio. These con tractors were selected on the basis of their experience with government research projects and their proximity to the Air Force Institute of Technology.

The single hypothesis to be verified in this study is that a Work Breakdown Structure model for Exploratory Development Research can be developed. Since there is virtually no guidance on developing a Work Breakdown Structure along any other line then the product/hardware orientation the project manager currently must rely almost entirely upon his/her own experience to structure his/her program in a way that will facilitate management control of Exploratory Research. Therefore, it was felt for this research that a minimal insight could be obtained from inexperienced program managers. Based upon this assumption, only those managers with a specfic level of experience were interviewed. The following criteria qualified a project manager as experienced:

1. A grade or equivalent grade of GS-11 or above.
2. At least five years experience as a program manager.
3. Must have worked on Exploratory Development Research projects.

A total of fourteen project managers were interviewed. Table 2-1 contains a breakout of the number of managers

TABLE 2-1: Interview Per Laboratory

Laboratory	Number
Avionics	2
Aero Propulsion	3
Flight Dynamics	5
Materials	4
TOTAL	14

interviewed at each lab. Also, one person was interviewed from each of the contractors. Since the nature of some of the interview questions required more than one or two word answers, the interview questions were electronically recorded with a cassette tape recorder. All project managers and contractor personel were asked for permission to record the interviews prior to their start. In addition, all interviews were conducted in the project manager's/contractor's office.

Prior to the development of interview questions a literature search was conducted to gather backgroud information. The following sources were consulted to gather information on research being conducted in the area of Work Breakdown Structure: Defense Technical Information Center (DTIC); Defense Logistics Studies Information Exchange (DLSIE); Air University Library Index to Military Periodicals; Readers Guide to Periodical Literature; RAND; and HQ Air Force Systems Command. The literature search found very little on Work Breakdown Structures. Almost all the information found on Work Breakdown Structures came from DTIC and DLSIE. In addition, all the information retrieved from DTIC was found through DLSIE, but not all the information found through DLSIE was contained in DTIC. After conducting the interviews a post-literature search was conducted in the area of management control of research and development. This information was used to help analyze the data gathered during the interviews.

Interview Questions

The interview questions were divided into three general categories. The first category of questions were used to determine if the program manager met the experience criteria outlined in the scope of the effort. The second category of questions were used to gather data to determine some of the characteristics of Exploratory Development Research. Finally, the third category of questions were used to determine the schmatic contents of a Work Breakdown Structure for Exploratory Development and the methodology used to develop that structure.

Questions 1 through 3 provided demograhpic data on the experience level of the project managers interviewed. Definitions for the R&D categories of research can be found in Chapter Three. Laboratory research can usually be classified under one of the R&D categories. As discussed earlier, project managers must rely upon their own experience to structure their work. Therefore, only those managers with a specific level of experience could provide the insight needed to determine an appropriate Work Breakdown Structure model for management control of Exploratory Development Research.

Questions 4 through 6 provided data on characteristics of Exploratory Development Research. The quesions asked the project manager to classify his/her projects according to the type of work being performed, the end result of the work and the average dollar value of the work. These Questions were designed to address the first of the secondary

objectives: Identify characteristics of Exploratory Development Research that influence management development. Projects classified as studies deal with the development of a new concept or a variation of an old concept and usually results in a final report or test samples. For the purpose of this thesis hardware projects are defined as those items which are a fabricated component, such as an integrated circuit or laboratory test equipment. Test oriented work units usually consist of projects where a component or several components are subject to enviromental testing. Finally, software development is defined as those work units whose end items is the delivery of a set of computer codes. The structure needed to manage research projects is greatly influenced by the characteristics of the work. Therefore, these questions provide the insight needed to determine the form, the level of detail and the uses of a Work Breakdown Structure in Exploratory Development Research.

Questions 7 through 9 were designed to determine the type of structures currently being used by project managers to monitor and control their work units. Therefore, the purpose of these questions was to address the second of the secondary objectives: Identify the type of structures currently being used by laboratory project managers to monitor and control Exploratory Development work units. Since none of the project managers interviewed during preliminary data gathering used a formal Work Breakdown Structure, questions

referencing Work Breakdown Structures were modified to reference the Statements of Work along with the Work Breakdown Structure. It was felt that the format used to structure the requirements section of the Statements of Work could be used to develop an appropriate Work Breakdown Structure model for Exploratory Development Research.

Questions 10 through 12 were designed to stimulate an open discussion of the process the project manager goes through to develop a Work Breakdown Structure/Statements of Work. It was during this discussion that the project manager had the opportunity to express what he felt were the primary factors to be considered and also the potential usefulness of a Work Breakdown Structure for management control of Exploratory Development Research.

Data Analysis

Responses to the interview questions are presented in Appendix B. For those questions requiring a single word or numeric answer, responses are presented in tabular form. While, questions requiring an in-depth answer the responses are presented in textual form. All interview responses along with the post-literative search and the review of Statements of Work for Exploratory Development Contracts were tabulated and compared to:

1) Identify characteristics of Exploratory Development Research,

2) Identify the type of structure used by laboratory projct managers to monitor and control Exploratory Development Research,

3) Identify the process laboratory managers go through to develop structures used to monitor Exploratory Development projects.

Finally, based upon the results of the analysis a Work Breakdown Structure model is proposed for use in controlling Exploratory Development Research projects. The results of the analysis is presented in Chapter Four.

Limitations

Limitations with regards to the scope of the research effort and the methodology by which the data was collected and analyzed are discussed in the following paragraphs.

This study was not an attempt to arrive at a universal Work Breakdown Structure that would be applicable to all research projects within Air Force laboratories, nor was the objective to solve all of managements' control problems. It must be realized that each laboratory has a unique mission and therefore different procedures and guidelines for accomplishing that mission. After concluding the interviews it became apparent that the mission even varied between the divisions within the laboratory. Since only the laboratories at AFWAL were used in the study, the technique used by other Air Force laboratories were not taken into considera-

tion. Even though the missions varied between laboratories and the divisions within them, there was a high degree of commonality in their procedures used to accomplish their missions. Therefore, this thesis effort was meant only to develop a model that could be used for tailoring Work Breakdown Structures to the individual needs of the program managers.

The second limitation concerns the method used to gather the research data. As discussed, earlier, the use of a questionnaire was rejected because of its inherent lack of flexibility in collecting non-statistical cata. Therefore, the interview method was chosen because of its distinct advantage of being flexible. However, one distinct disadvantage of interviews lies in the diversity of response. Thus, some of the responses cannot be grouped into clear-cut categories from which general observations can be derived. For example, what process does an engineer go through to develop a Work Breakdown Structure or Statement of Work. The answer to this question varied from a few words to several paragraphs. Obviously, with so many varied answers only the most general conclusions can be drawn. In addition, the time consuming nature of the interviews (30-45 minutes) precluded sampling a large number of project managers.

The final limitation concerns the interview method itself. As mentioned earlier the majority of the interviews were electronically recorded on a cassette tape recorder.

Due to problems with the tape recorder some responses to interview questions were lost. Therefore, the researcher either omitted that response from the analysis or relied upon notes that were taken during the interviews. In addition, several questions were added to the interview process toward the end of the data collection. The analysis of these questions did not include responses from all the project managers interviewed.

CHAPTER 3

WORK BREAKDOWN STRUCTURES

This chapter provides an in-depth discussion of a Work Breakdown Structure as defined by MIL-STD-881A. The different types of Work Breakdown Structures and the uses of a Work Breakdown Structure will be covered. The use of Work Breakdown Structures in Air Force research and developing is increasing. The different types of research within the Air Force will be presented in this chapter.

MIL-STD-881A (32:2) defines a Work Breakdown Structure as:

> ...A product-oriented family tree composed of hardware, /software/, services and data which result from project engineering efforts during the development and production of a defense material item, and which completely defines the project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product.

The three important concepts to remember from the above definition is that the Work Breakdown Structure:

1. Is a product-oriented family tree composed of hardware, software, and other work tasks.

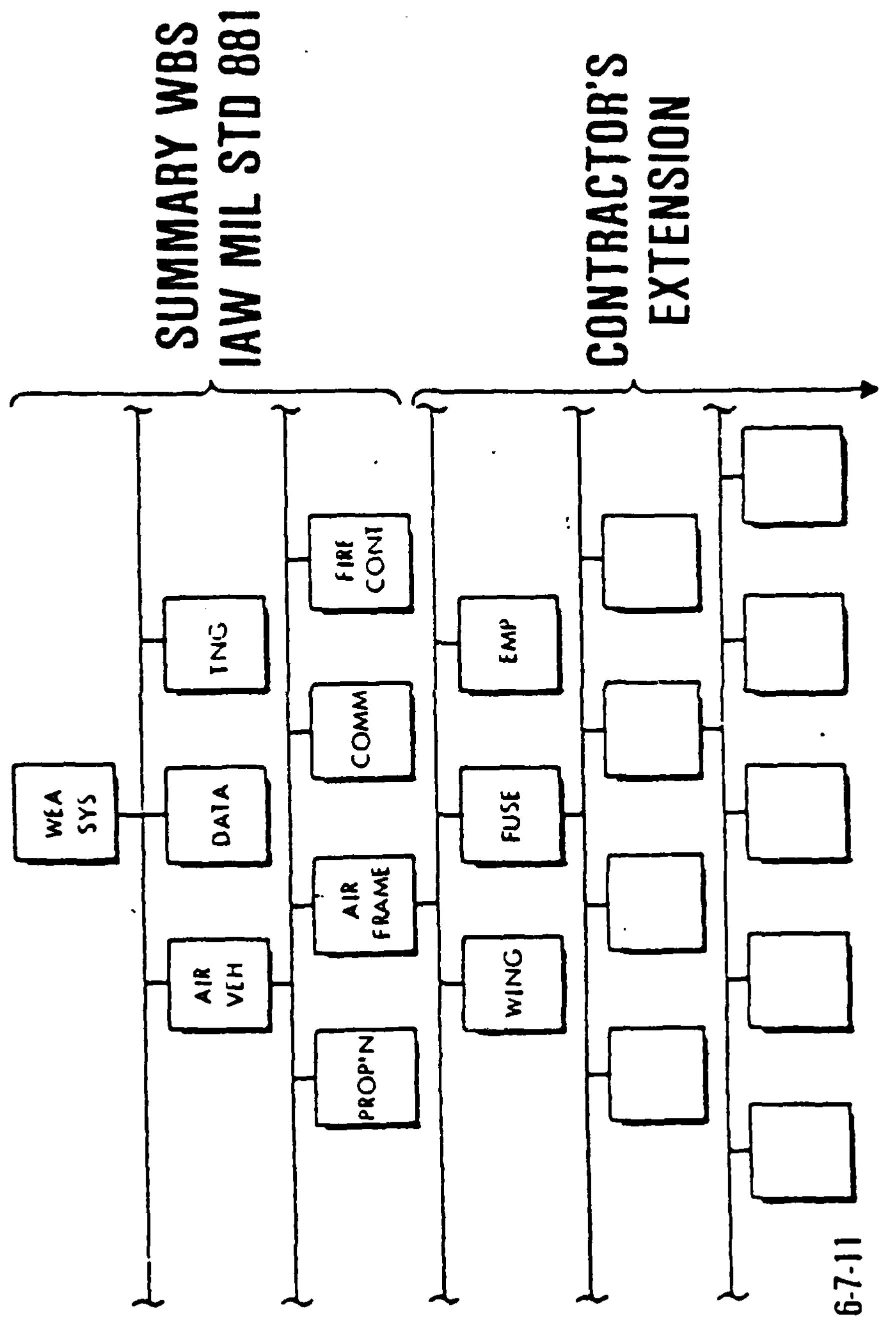
2. Completely defines the project/program.

3. Relates elements of work to each other and to the end product.

Figure 3-1 shows the basic organization of a Work

FIGURE 3-1

Work Breakdown Structure Organization



Breakdown Structure. For a major weapon system program, the upper three levels of the Work Breakdown Structure are composed of work elements defined in the appendixes of MIL-STD-881A. Level 1 is defined as the entire defense material item being procured. A defense material item is any system usually established as an integral program element or associated with a project within a program element, for example: Minuteman ICBM system, B-1B aircraft system, or Maverick missle system. The major elements of the defense material item comprises level 2 or the Work Breakdown Structure, for example: An air vehicle, a space vehicle, an aggregation of services, data. Finally, level 3 of the Work Breakdown Structure is the components subordinate to the level 2 major elements, for example: An airframe, a propulsion unit, a type of service, or an item of data. Any extension of the Work Breakdown Structure below level 3 is performed by the contractor. The contractor extends to the Work Breakdown Structure to the lowest levels needed to fully define and manage the contract.

The upper three levels of the Work Breakdown Structure has been organized within the following seven categories of defense material items:

1. Aircraft Systems
2. Electronics
3. Missle Systems
4. Ordnance
5. Ship
6. Space
7. Surface Vehicle

MIL-STD-881A provides a Summary Work Breakdown Structure and definitions of the elements within the Summary Work Breakdown Structure for each of the seven categories of defense material items. An example of a Summary Work Breakdown Structure and definitions can be located in Appendix D.

There are four basic types of Work Breakdown Structures defined in MIL-STD-881A.

1) The <u>Summary Work Breakdown Structure</u> is comprised of the upper three levels of a Work Breakdown Structure for one of the defense material items. The Summary Work Breakdown Structure can simply be found in the appendixes of MIL-STD-881A. That is, the seven major categories of defense material items comprise all the Summary Work Breakdown Structures.

2) The <u>Project Summary Work Breakdown Structure</u> is a Work Breakdown Structure that has been tailored to meet the needs of the program manager. The Work Breakdown Structure has been tailored by selecting those elements from one or more of the Summary Work Breakdown Structures that meet the needs of the program manager. If the elements of the Summary Work Breakdown Structure are insufficient because of unique configurations or other special features of the project, the program manager can add or substitute Work Breakdown Structures to make up the Project Summary Work Breakdown Structures.

3) The <u>Contract Work Breakdown Structure</u> is the

Project Summary Work Breakdown Structure elements contracted by the program manager plus the extension of the Project Summary Work Breakdown Structure by the contractor to its lowest levels. Therefore, the Contract Work Breakdown Structure portrays all the products and work that has to be done to accomplish a specific contract.

4) The Project Work Breakdown Structure is the complete Work Breakdown Structure for the project. It contains all the Work Breakdown Structure elements related to the development, modification, and/or production of a defense material item. The Project Work Breakdown Structure is developed by merging all the various Contract Work Breakdown Structures with the Project Summary Work Breakdown Structures.

The use of a Work Breakdown Structure is mandatory for the following types of projects (32:1);

1. All defense material items (or major modifications) being established as an integral program element of the 5-year defense program (FYDP),

2. All defense material items (or major modifications) being established as a project within an aggregated program element where the project is estimated to exceed $10 million in RDT&E financing, and

3. All production follow-on or (1) and (2) above.

The Work Breakdown Structure may be used for the research, development, and/or production of any project at the discretion of the project manager.

Air Force policy on the development and application of Work Breakdown Sturctures encourages the project manager to "tailor a preliminary project WBS for each program or project entering a validation, full scale development, or production phase /31:1/." Using the preliminary Project Work Breakdown Structure, the project can develop the preliminary Contract Work Breakdown Structure and prepare the individual Statements of Work. The project manager should tailor the preliminary Project Work Breakdown Structure using the elements from the categories provided in MIL-STD-881A. This is to establish a degree of unity between Work Breakdown Structures. The project manager may substitute elements if the Work Breakdown Structure elements in MIL-STD-881A "are inappropriate, require modification, or if new elements are needed /31:1/." Air Force policy requires the use of a single Work Breakdown Structure on each project, program, and contract. Contractors are encouraged to use a single Contract Work Breakdown Structure and to up date it as additional system definition is accomplished.

A Work Breakdown Structure provides a consistant and visible framework that facilitates (31:2):

1. Planning
2. Assigning responsibilities
3. Monitoring and Controlling the status of
    a) Engineering efforts
    b) Resource allocations
    c) Cost estimates
    d) Procurement actions
    e) Expenditures
    f) Cost/Schedule/Technical Performance

4. Display and definition of the total system
5. Compatability among data requirements

The Work Breakdown Structure used as a management tool provides the common integrating thread between its elements, other program or project management practices and products, such as: Statements of Work; Contract line items and end items; and technical and management reports (31:2). The Work Breakdown Structure as a management tool is being used by project managers in research and development at an increasing rate.

Air Force research projects are divided into four types of research.

Research (6.1)

Defense research is scientific study and experimentation directed toward increasing knowledge and understanding in those fields of the physical, engineering, environmental, biological-medical, and behavioral-social sciences related to long-term national security needs. It provides fundamental knowledge for the solution of identified military problems. It also furnishes part of the base for subsequent exploratory and advanced development in defense-related technologies and of new or improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation energy conversion, materials and structures, and personnel support /7:17/.

Exploratory Development (6.2)

Includes all effort directed toward the solution of broadly defined problems, short of major development programs, with a view to developing and evaluating technical feasibility. This type of effort may vary from fairly fundamental applied research to major subsystems /7:17/.

Advanced Development (6.3)

Advance development is the extension of the concepts created in exploratory development, along with known technological limitations, to create an operating prototype device or process. The goal of this implementation is to demonstrate technical feasibility of the concepts and to establish, by test, the operating parameters of the device or process as well as to discover those gaps and limitations that may require additional applied research or exploratory development for the device or process to be completely successful [11:143-144].

Engineering Development (6.4)

Engineering Development is the application of practical constraints such as economical requirements, manufacturability, limitations, field maintainability, and the like, to the practical implementation of an objective that is well defined in a conceptual and physical sense. The end purpose of the engineering development phase is to produce a process or device ready for full-scale production and field operation [11:144].

CHAPTER 4

RESULTS AND FINDINGS

This chapter discusses the results and findings of the interviews. Responses to the twelve interview questions are analyzed and a summary of the results is presented. An in-depth presentation of the responses to the interview questions can be found in Appendix B. The information presented in this chapter is divided into four sections. The first section deals with demographic data collected on each project engineer to insure they met the experience criteria presented in Chapter 2. Section two describes some characteristics of Exploratory Development Research that affect the type of Work Breakdown Structure needed for management control. The current structures used by project engineers to manage their work units is discussed in section three. Finally, section four summarizes the process and primary factors of developing a Work Breakdown Structure/Statement of Work.

Demographics

The primary objective of this research is to present a Work Breakdown Structure format that could be tailored by the project engineer to fit his/her, particular research project. Since there is little guidance on developing a Work Breakdown Structure for Exploratory Development projects,

the project engineer must rely on his/her, or other project engineers, experience to structure his/her program in a way that will facilitate management control. Therefore, only those engineers with a specific level of experience were interviewed. A set of criteria was established to determine whether the project engineer qualified as experienced.

The first criteria established that the project engineer had to have a grade of GS-11 or above. Table 4-1 summarizes the grade structures of the project engineers interviewed. All the project engineers interviewed were recommended by their division or branch chief to participate in this research study. The division and branch chiefs recommended all civilians to be interviewed by the researcher. The fourteen project engineers interviewed were evenly distributed in grades. All the project engineers interviewed met the first criteria established.

The second criteria required the project engineer to have at least five years experience in program management. Table 4-2 summarizes the program management experience of the project engineers interviewed . Over sixty percent of the engineers interviewed had at least twenty years experience as a program manager. Only one project engineer had less than ten years experience in program management. Those engineers who are GS-12s have an average of 16.8 years as a program manager. The project engineers with a grade of GS-13 have an average of 22.5 years in program management.

Table 4-1: Program Engineer Grades

Rank/Grade	Responses	Percentage of Total Responses (%)
GS-12	5	35.7
GS-13	4	28.6
GS-14	5	35.7
TOTAL	14	100.0%

Table 4-2: R&D Project Management Experience

Years	Responses	Percentage of Total Responses (%)
10	1	7.1
10-14	1	7.1
15-19	3	21.4
20-24	6	42.9
25-30	2	14.3
30	1	7.1
TOTAL	14	99.99%*

GS-12 MEAN ($\bar{x}$) = 16.8 years

GS-13 Mean ($\bar{x}$) = 22.5 years

GS-14 MEAM ($\bar{x}$) = 21.6 years

* Percentages do not sum to 100% due to rounding.

All the project engineers interviewed met the second criteria.

To meet the final criteria used to determine the experience level of the project engineer, he/she must have worked with Exploratory Development Research projects. Table 4-3 summaries the number of project engineers working in the different research and development categories. All the project engineers interviewed had some experience with Exploratory Development Research. Half the engineers interviewed also had experience managing other categories of research and development. Twenty-one percent have worked with Basic Research projects, while the other twenty-nine percent worked with Advanced Development projects. Those engineers who have experienced working with Basic Research are currently working with Exploratory Development Research spend their time working with Advanced Development Research projects.

Characteristics

The reader should note that the example presented in this section were provided by the project engineers interviewed. The examples do not encompass all the work being performed within the laboratories

Project engineers working with Exploratory Development Research encounter a wide variety of projects. The projects range from studies and tests to software and hard ware development. Table 4-4 summarizes the engineers' classification of the projects they have worked on. Only 28.6

Table 4-3: R&D Category

R&D Category	Responses	Percentage of Total Responses (%)
6.1-6.2	3	21.4
6.2	7	50.0
6.2-6.3	4	28.6
TOTAL	14	100.0%

The majority of respondents who managed combinations of work units currently work primarily with Exploratory Development (6.2) work units.

percent of the engineers interviewed worked solely on study projects, while the other 71.4 percent worked on a combination of study, hardware, software and testing projects.

The study projects were exploring a new concept or a variation upon an old concept. An example of a study would be exploring different tip treatments for aircraft blades to prevent chipping. A natural continuation of this particular study project would be to demonstrate the results of the study by coating a section of an aircraft blade and performing structual tests. This demonstration of a concept, using a small section of an aircraft, is classified by most project engineers as hardware development. Hardware development usually entails the building of a small piece of structure used to demonstrate a new concept or to look at the application of a new material or manufacturing process. The technology developed with that piece of hardware is from a design analysis and fabrication point of view. Basically, the hardware developed is not meant to be applied to any particular weapon system, but to demonstrate a concept that can be used in later stages of research and development. However, there is a small portion of hardware development within the Exploratory Development Research field that results in a usable end item. An example would be device development which takes an architecture or algorithm and builds an integrated circuit that can perform the algorithm. Another example is the development of test equipment used within the laboratory and

Table 4-4: Project Classifications

Type	Responses	Percentage of Total Responses (%)
Studies	4	28.6
Hardware	1	7.1
Studies/Hardware	7	50.0
Studies/Software/ Hardware/Test	2	14.3
TOTAL	14	100.0%

in the field.

The deliverables underExploratory Development contracts confirm the discussion on hardware projects. Those project engineers working with hardware contracts reported the normal deliverables under their contracts consisted of technical reports, preliminary specifications, test plans, specimens, panels or samples of coatings. The deliverables for those hardware projects with an usuable end item were mainly instrumentation and test equipment. Those projects classified as studies had deliverables of final reports.

The majority of the work within Exploratory Development field deal with the development of new concepts and the demonstration of these new concepts. Those concepts are demonstrated on small structual panels or sub-scale samples and do not entail the fabrication of an usable end item. The majority of the deliverables under these Exploratory Development projects are technical and final reports, test specimens, test plans and preliminary specifications. Therefore, a Work Breakdown Structure along the traditional hardware orientation as presented in MIL-STD-881A is not appropriate for Exploratory Development Research. The Work Breakdown Structure for Exploratory Development Research projects should follow the way the work is being performed to be a meaningful management tool. Following sections will deal with how the work is being structured within Exploratory Development Research.

The final characteristics of Exploratory Development Research to be discussed is the average dollar value of contractual work units. Table 4-5 summarizes the project engineers' response to the average dollar value of his ocntracts. Approximately eighty-six percent of the engineers responding reported their ocntracts average dollar value at less than \$1 million. Since the majority of contracts are low in value, the project engineer does not need an in-depth Work Breakdown Structure to control and monitor their work. This effects the type of Work Breakdown Structure needed. It also influences the Work Breakdown Structure's level of detail.

Formats

The project engineers interviewed within the Air Force Aeronautical Laboratories use three formats to structure their Statements of Work: Phase, Milestone, or Task. Table 4-6 summarizes how many project engineers used each format to structure their work. The basic work being organized under each of the different formats was the same. Since approximately eighty-six percent of the engineers used a phase type format, it will be used to describe the work performed on a typical Exploratory Development project. The first phase of an Exploratory Development Research project would be a study. Under the study phase the contractor would analyze the problem or concept and then propose how to solve the problem or approach the concept. In the second phase of the research

Table 4-5: Average Dollar Value of Contractual Work Units

Dollars	Responses	Percentage of Total Responses (%)
<$100,000	2	14.3
$100,000-$1,000,000	10	71.4
>$1,000,000	2	14.3
TOTAL	14	100.0%

Table 4-6: Work Breakdown Structure/ Statements of Work Formats

Format	Responses	Percentage of Total Responses (%)
Phase/Task	10	71.4
Phase/Milestone	2	14.3
Task/Subtask	2	14.3
TOTAL	14	100.0%

project the contractor would develop a set of preliminary designs for an integrated circuit, test specimens, sub-scale sample or panels. After the project engineer reviews the preliminary designs with the contractor, a set of final designs are are developed, phase three. After the final design is reviewed, the contractor goes into a fabrication phase. In this phase, he fabricates the test specimens, sub-scale samples and panels needed to prove the design concept developed in the previous phases. The final phase is to perform and evaluate structual and environmental tests on the sample fabricated.

The phase format is primarily used when you have consecutive pieces of work to be performed; study, design, fabrication, test, and evaluation. The phase milestone format is used when you have decision points built into the Statement of Work. At the completion of a milestone, for example preliminary design, the project manager reviews the work performed and decides whether to move into the next phase, detail design. If the project engineer does not feel the results are going to help him/her reach his/her goal they would either have the contractor repeat the phase just completed or end that particular avenue of pursuit. The task format is used when parallel pieces of work are being performed. For example, if a project engineer had a project to design a structual panel using three different composites, he/she would break the work into structual panel design A,

structual panel design B and structual panel design C. In this instance the work on one structual panel need not wait until work on another panel be completed. Nor does work on one panel depend on the acceptance or rejection of the work performed on the other panels.

To track their contractional work units, the project engineer uses the same format that his Statement of Work is written in. Schedule data is presented in a phase/task and subtask format. On the other hand, financial information is submitted by phase or task. It is then broken into functional categories. Under each phase, the contractor reports dollars and manhours by functional categories. This same breakout is used by the contractors as one of the formats used to present his/her price proposal in response to a Request for Proposal. The contractor presents functional cost associated with each phase or task of the contract.

Exploratory Development Research deals with the investigation of a new concept or a variation on an old one. The work performed ranges from studies and design to fabrication, test and evaluation. What is usually designed and fabricated is a test specimen or some sub-scale panel. traditional hardware Work Breakdown Structure is not appropriate for tracking this type of research. The Work Breakdown Structure needs to provide a format that tracks the work the way it is organized and performed. Projects at the Air Force Wright Aeronautical Laboratories are organized into

phases and tasks. The contractor is instructed through the Statement of Work what needs to be performed under each phase and task. Example of Statements of Work from the Air Force Wright Aeronautical Laboratories can be found in Appendix C. The project engineers then track the work using the same phase and task format of the Statement of Work. Schedules are broken out into phases and tasks and subtasks. Because of the low dollar value of the contracts, the project engineer receives financial data only at the phase or task level. The financial data is presented in a functional breakout under each phase or task. Therefore, the researcher feels that an appropriate Work Breakdown Structure format for Exploratory Development Research should be along a phase/task orientation.

Process/Primary Factors

The process used by each project engineer to write his Statement of Work was highly individual oriented. Most project engineers started out with an objective or goal in mind. If a project is study oriented the goal might be to answer a question, while a hardware project goal might be to design and test a structual concept for a piece of hardware. The project engineer then develops an approach to solving the problem or reaching the goal. The detail of the approach is governed by many factors. One factor to be considered is the maturity of the research. If the project is extending

the capability of a concept the there exists quite a bit of background information. Therefore, the approach to reaching the goal of the project would be fairly detailed. On the other hand, if the project deals with a new concept with very little backgroud information then the approach would be broad so as to investigate all possible avenues. Another factor to be considered is the potential contractors. Each contractor may have a different process to fabricate a test panel. The project engineer may only wat to specify the composite to be used. By specifing the fabrication process he/she may exclude potential contractors.

The approach to solving the problem is usually based on how the project engineer would perform the work himself/herself. The nature of the tasks is pretty well dictated by experience. What has proven more or less successful in the past is generally used for future projects. These are the events the program engineer feels is needed to reach the goal of the project. The work may be similar in over-all design to other jobs, but the specifics must be tailored for each individual project. Once the project engineer has determined his/her approach, milestones are assigned to the asks that need to be performed. These milestones are in terms of time and dollars needed to accomplish each task.

In Exploratory Development Research the project engineer is investigating items that have a military application. The project engineer may be looking at the development of

structual concepts, composites or material coatings. An important factor to be considered is the payoff of the research in terms of systems application. Can the weight of the system be decreased? Can the Life Cycle Cost of the system be decreased? Can we increase the range of a weapon system? Can the maintainability of the structure be enhanced? Another primary factor to be considered along with the payoffs of the research is the funding level. The scope of the research must stay within the funding levels of the project. Time is not an important factor to Exploratory Development Research until the project goes on contract. At that time schedules are mainly affected by the funding of the project. Any slippage in schedule usually results in the need for additional funding. In terms of system application, scheduling is not all that critical. Most Exploratory Development Research is performed to develop and demonstrate a new concept. This new concept is not immediately applied to current weapon systems. but once fully developed is used by project engineers within the Advanced Development Research field.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the major conclusions drawn from this research effort. Based upon these conclusions a Work Breakdown Structure for management control of Exploratory Development Research will be recommended. The conclusions and recommendations will be grouped into three major sections:

1. Characteristics of Exploratory Development Research.
2. Format Structure used by project engineers.
3. Miscellaneous conclusions and recommendations.

Characteristics of Exploratory Development Research

The primary work done within the Exploratory Development field deals with the development and demonstration of new concepts or variations on existing concepts. Sub-scale samples or small structual panels are used to demonstrate these concepts. Demonstration of a concept at this stage of research and development does not entail the fabrication of a usable end item, such as an aircraft engine or a guidance system. Project engineers explore concepts that deal with the development of tip treatments for aircraft blades, the

use of new composites for wing structures, or the development of new heat resistant paints. Normally the deliverables for these Exploratory Development projects are technical reports, small scale panels, test specimens, test plans, or preliminary specifications. The products developed are not meant to be applied directly to any particular weapon system, but used to demonstrate a concept that can be used in later stages of research and development. In some cases a unique piece of test equipment or instrumentation is developed to be used solely within the laboratory.

Since Exploratory Development Research projects do not involve the design and fabrication of a usable end item, such as an aircraft engine or guidance system, a Work Breakdown Structure along the traditional hardware orientation presented in MIL-STD-881A is not appropriate. Only one of the Statements of Work reviewed (Exhibit C-1 in Appendix C) included a Work Breakdown Structure. In addition, none of the project engineers interviewed used a Work Breakdown Structure to manage their Exploratory Development projects. Two reasons were attributed to the lack of use of a Work Breakdown Structure. First, those project engineers working solely with Research (6.1) and Exploratory Development Research (6.2) projects were not familiar with the concept and uses of a Work Breakdown Structure. Secondly, those project engineers working with Exploratory Development Research (6.2) and Advance Development Research (6.3) projects viewed the

concept of a Work Breakdown Structure along the hardware orientation presented in MIL-STD-881A. Therefore, they felt a Work Breakdown Structure was inappropriate for Exploratory Development Research. The primary conclusion drawn is that a Work Breakdown Structure for Exploratory Development Research must follow the way the work is being performed to be a meaningful management tool.

Approximately eighty-six percent of the project engineers reported that the average dollar value of the Exploratory Development projects were less than $1 million. Since the majority of the projects are low in dollar value the project engineer does not need an in-depth management system to control his/her work. Currently the project engineer tracks his/her schedule by phases and tasks under each phase. On the other hand, the project engineer only tracks functional cost by phases. This influences the level of detail of the Work Breakdown Structure needed to control Exploratory Development projects. Advanced Development projects ranging from $2 million on up normally use a 3 level Work Breakdown Structure. Therefore, the researcher feels that a Work Breakdown Structure broken down to level 2 or 3 would provide sufficient detail for the project engineer to monitor his/her projects.

In this section characteristics of Exploratory Development Research affecting the Work Breakdown Structure needed for management control were discussed. Two major con-

clusions were drawn from the discussion.

1. A Work Breakdown Structure along the traditional hardware orientation presented in MIL-STD-881A is inappropriate for Exploratory Development Research. To be a meaningful management tool, the Work Breakdown Structure must follow the way the work is being performed.

2. A Work Breakdown Structure broken down to level 2 or 3 will provide sufficient detail for management control of Exploratory Development Research.

Format Structures Used By Project Engineers

The project engineers at the Air Force Wright Aeronautical Laboratories used three formats to structure their Statements of Work: Phase/Task, Phase/Milestone, Task/Subtask. The Phase/Task format is primarily used when the Statement of Work is organized into consecutive pieces of work to be performed. If decision points are built into the Statement of Work the project engineer used a Phase/Milestone format. Finally, the Task/Subtask format is used when parallel pieces of work are to be performed. The project engineer uses these same formats to track his/her costs and schedule. Although the purpose for using each format is different, the basic work being performed is the same. Exploratory Development projects go through the following stages:

1. Conception

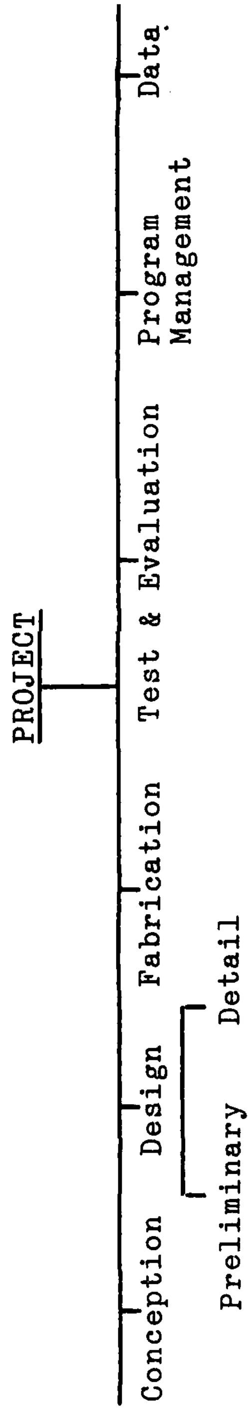
2. Preliminary Design
3. Detail Design
4. Fabrication
5. Test and Evaluation

Even though Exploratory Development project follow the above stages, the detailed tasks for each stage is project specific. Therefore, the conclusion reached is that a Work Breakdown Structure along a phase orientation be used. Since the tasks under each phase is dependent upon the project only a level 2 Work Breakdown Structure is recommended. Figure 5-1 displays the Work Breakdown Structure recommended by the researcher.

The conceptual phase deals with defining the problem or setting the goal. It is during this phase that literature searches are performed to gather background material on work being done in the area or on similar projects. During this phase the approach to solving the problem or reaching the goal is formulated. The definition process involves feasibility assessments, tradeoff studies and analysis. For example, if the goal is to develop a wing structure using a new composite; during the conceptual phase you identify the type of composites you might use. Feasibility assessments and tradeoff studies are performed to narrow down the list of composites to those that will be used in the next phase of the research. During the conceptual phase you define the problem, conduct background searches, formulate the approach, identify the technology needed and perform feasibility assessment and tradeoff studies.

FIGURE 5-1

Recommended Work Breakdown Structure
For Exploratory Development Research



The design phase takes the results of the conceptual study and designs the hardware or software needed to assess the concept. The design phase does not always entail the design of a usable end item. Instead a small wing panel or a sub-scale sample may be designed to prove the concept developed. Once the design has been completed, the panel or sample is fabricated based upon the designs. The fabrication phase involves applying the materials, technology and/or concepts developed during the conceptual phase of the project. After the hardware has been fabricated environmental and structual tests are conducted to prove the feasibility of the concepts developed. If the hardware fails any of the tests the project engineer may have to go as far back as the conceptual phase to correct the problems. Or the project engineer may conclude the concept is not feasible and end the research there.

Two additional elements of the recommended Work Breakdown Structure, which would not be considered phases, are project management and data. Project management refers to the business and administrative functions needed to accomplish the over-all project objectives which are not associated with any specific phase. Examples of these activities would be cost/schedule/performance measurements, contract management, data management, etc. The data element refers to all data items listed on the Contract Data Requirements List (CDRL).

MIL-STD-881A (32:27) goes on to further define data:

> This element includes only such effort that can be reduced or will not be incurred if the data item is eliminated. If the data are government peculiar, include the efforts for acquiring, writing, assembling, reproduction, packaging and shipping. It also includes the effort for repreparing into government format with reproduction and shipment if data are identified to that used by contractor, but in different format.

If the project involves the design and fabrication of an usable end item then the Work Breakdown Structure should center around that end item. For example, Figure 5-2 is a Work Breakdown Structure for the development of an Integrated Circuit. The level 2 integrated circuit element is further broken down into the tasks needed to develop an integrated circuit.

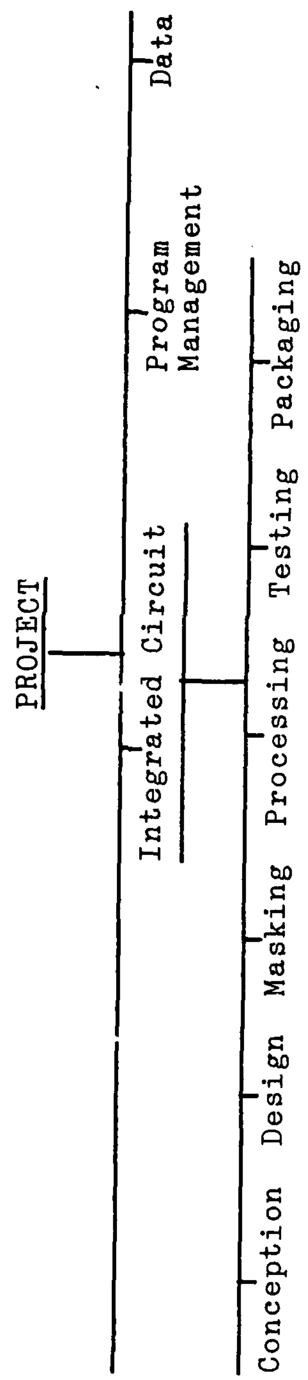
Miscellaneous Conclusions and Recommendations

The previous sections presented several conclusions and recommendations regarding the format of a Work Breakdown Structure for management control of Exploratory Development Research. In this final section some miscellaneous conclusions drawn from the study are discussed.

This research effort focused on experienced project engineers to determine the format of a Work Breakdown Structure for Exploratory Development Research. This was based upon the assumption that inexperienced project engineers would provide limited information in this area. The interviews conducted indirectly supported this assumption. The experienced program engineers were not able to give specific

FIGURE 5-2

Work Breakdown Structure For
An Integrated Circuit



methodologies for developing a Work Breakdown Structure or Statement of Work except for experience and the uses of past Work Breakdown Structures and Statements of Work. Therefore, it is doubtfûl whether inexperienced project managers could have provided insight on the type of information and training needed to provide guidance on the development and use of a Work Breakdown Structure. This author recommends a study be conducted which focuses on the information needed by a novice project engineer to monitor and control his research projects. This should include the concept and uses of a Work Breakdown Structure for management control of research projects.

The main objective of this research was to identify a format to be used in developing a Work Breakdown Structure for Exploeatory Development Research. The format chosen was the current one used by the project engineers at the Air Force Wright Aeronautical Laboratories to structure their Statements of Work. This format is also used by the project engineers to collect cost and schedule data. The research did not involve assessing the effectiveness of this format to control cost and schedule. The researcher highly recommends a study be conducted to assess the validity of controlling Exploratory Development Research using a Phase/Task control structure.

As a final cimment, it is stressed that further research in the area of management control of Exploratory Development Research is required. This study was not con-

cieved to solve all of management's control needs. The objective of this thesis was to provide program engineers with a Work Breakdown Structure model that could be tailored to their individual needs. Some of the recommendations in this chapter require little effort to implement, such as the use of a Phase/Task Work Breakdown Structure in Exploratory Development Research. While other recommendations would require more time, such as the development of information on the ocncept and use of a Work Breakdown Structure for management control of Exploratory Development Research.

APPENDIX A

INTERVIEW QUESTIONS

1. Rank/Grade
2. Years of R&D project management experienc.
3. Generally, with what R&D category do you work with Basic Research (6.1), Exploratory Development (6.2), Advanced Development (6.3).
4. Would you classify your projects as studies, hardware development, software development or test oriented.
5. What were the deliverables under your contractual work units?
6. What was the average dollar value of your contractual work units?
7. What WBS/SOW format do you currently use to manage your projects- hardware, system, functional, task?
8. What format does the contractor use to provide cost and schedule data?
9. In response to the Request for Proposal, what format did the contractor use to present his/her cost proposal?
10. What was the process you went through to develop a WBS/SOW?
11. What do you feel are the primary factors to be considered when developing a WBS/SOW?
12. What sources did you use while developing a WBS/SOW?

APPENDIX B

THE INTERVIEW

1. Rank/Grade

PROJECT ENGINEER	LABORATORY	RANK/GRADE
Alexander	Flight Dynamics	GS-14
Beachler	Flight Dynamics	GS-14
Boensch	Flight Dynamics	GS-14
Couturier	Avionics	GS-12
Hirsch	Aero Propulsion	GS-14
Hojnacki	Aero Propulsion	GS-13
Johnson	Materials	GS-12
Loptien	Flight Dynamics	GS-13
O'Hara	Materials	GS-13
Petty	Aero Propulsion	GS-13
Phillippi	Materials	GS-12
Ramsey	Flight Dynamics	GS-12
Schmitt	Materials	GS-14
Smith	Avionics	GS-12

2. Years of R&D project management experience.

PROJECT ENGINEER	YEARS OF EXPERIENCE
Alexander	21
Beachler	24
Boensch	18
Couturier	8
Hirsch	25
Hojnacki	20
Johnson	11
Loptien	31
O'Hara	19
Petty	20
Phillippi	29
Ramsey	20
Schmitt	20
Smith	16

3. Generally, with what R&D category do you work with---
Basic Research (6.1), Exploratory Development (6.2), Advanced Development (6.3).

PROJECT ENGINEER	R&D CATEGORY
Alexander	6.2-6.3
Beachler	6.2-6.3
Boensch	6.2-6.3
Couturier	6.2
Hirsch	6.2
Hojnacki	6.1-6.2
Johnson	6.2
Loptien	6.2
O'Hara	6.1-6.2
Petty	6.1-6.2
Phillippi	6.2
Ramsey	6.2
Schmitt	6.2
Smith	6.2-6.3

4. Would you classify your project as studies, hardware development, software development, test oriented.

PROJECT ENGINEER	TYPE
Alexander	Studies/Hardware
Beachler	Studies/Software/Hardware/Test
Boensch	Studies/Hardware
Couturier	Hardware
Hirsch	Studies/Hardware
Hojnacki	Studies/Hardware
Johnson	Studies
Loptien	Studies
O'Hara	Studies
Petty	Studies/Software/Hardware/Test
Phillippi	Studies/Hardware
Ramsey	Studies/Hardware
Schmitt	Studies
Smith	Studies/Hardware

5. What were the deliverables under your contractual work units.

PROJECT ENGINEER	DELIVERABLES
Alexander	Instrumentation
Beachler	Test Equipment/Software
Boensch	Small Structual Panels
Couturier	Integrated Circuits/Test Equipment
Hirsch	Technical Reports/Hardware
Hojnacki	Technical Reports/Hardware
Johnson	Final Reports/Laser Windows
Loptien	Technical Reports
O'Hara	Techinal Reports/Sub-Scale Samples/Test Specimens/Preliminary Specifications
Petty	Final Reports/Software Code/Hardware
Phillippi	Laboratory & Field Instrumentation
Ramsey	Technical Reports/Test Plans/Display Items/Specimans/Panels/Complete Structures
S[illegible]mitt	Wet Samples of Coatings/Paint/Analytical Programs/Computer Printouts/Technical Reports
Smith	Final Reports

6. What was the average Dollar value of your contractual work units.

PROJECT ENGINEER	AVERAGE DOLLAR VALUE
Alexander	25K-100K
Beachler	1M-3M
Boensch	500K-1M
Couturier	200K
Hirsch	2.5M
Hojnacki	20-30K
Johnson	300-500K
Loptien	100-500K
O'Hara	200-300K
Petty	25-750K
Phillippi	500K
Ramsey	800K-1M
Schmitt	200-400K
Smith	600K

7. What WBS/SOW format do you currently use to manage your projects---hardware, system, functional, task.

PROJECT ENGINEER	FORMAT
Alexander	Phase/Task
Beachler	Phase/Milestone
Boensch	Phase/Task
Couturier	Task/Subtasks
Hirsch	Phase/Task
Hojnacki	Phase/Task
Johnson	Phase/Milestone
Loptien	Phase/Task
O'Hara	Phase/Task
Petty	Phase/Task
Phillippi	Phase/Task
Ramsey	Phase/Task
Schmitt	Phase/Task
Smith	Task/Subtasks

7. Continued........Some project engineers, in addition to one or two word responses, provided a more in-depth discussion of how they formated their WBS/SOW.

<u>Beachler</u>- Let's talk about a piece of hardware. Your first milestone would be a preliminary or conceptual design of what the hardware is going to look like. That would be a milestone when it is completed, preliminary design complete. At this point you review, decide, suggest and coordinate your move into the detailed design phase. At the completion of the detailed design phase of the hardware you have a review point. You look at the contractor's detailed design to see if you agree with it. If it looks like it has gotten you where you want to go, then you proceed into the construction of the thing. You call it a final design if you approve it. Then you go into fabrication. You have a distinct phase for each of these preliminary designs, detail design, and fabrication. At the end is your goal.

<u>Boensch</u>- Typically preliminary design would be phase 1, detailed design phase 2, fabrication phase 3 and testing phase 4. Basically the work breaks down by phases more than anything else. Then once you break it out into phases you break it out to whose contributing in the phases. How much engineering do I have to have, do you have manufacturing, quality or test. So you break it down basically by phase and under that the contribution by individual.

If you have a design phase where you are looking at

two or three options or two or three vehicles, you might want to break that down a little finer and say Design-Vehicle A, Design-Vehicle B, Design-Vehicle C. Break the work down to what ever you need to get the job done.

Couturier- If you are going to develop an integrated circuit, the task would be basically the development of that integrated circuit may be broken down into a study phase. How are we going to put this thing on a chip, will it all fit or will it become to big for the power. Then you go into the IC layout. The actual layout of the chip where everything will be. Then you go into mass making, the processing, the testing, the packaging. If the testing or packaging doesn't work then you go back until you get it to work. The task would be the IC development, the subtask would be each of the individual steps and the subtasks could be broken up further.

Phillippi- Where there is a piece of hardware as an end item, I break the work down into sequential phase/task. Where they are studies and data or information is the end product instead of hardware, there may be several parallel tasks.

Ramsey- Generally when you write a Statement of Work you'll break it up into phases or tasks. It's really based upon how you organize it. It should give you reported information from the contractor on financial or technical data. In many cases reporting level by phases, at level two is adequate.

The first phase may be nothing but a study type phase; next phase may be design and analysis; and the last phase

may be to build something, test it and correlate it back to your design.

8. What format does the contractor use to provide cost and schedule data.

PROJECT ENGINEER	SCHEDULE FORMAT	COST FORMAT
Alexander	NO RESPONSE	
Beachler	Milestone	Milestone/Functional
Boensch	Phase	Phase
Couturier	Task/Subtask	Task/Functional
Hirsch	NO RESPONSE	
Hojnacki	NO RESPONSE	
Johnson	NO RESPONSE	
Loptien	Phase/Task	Phase/Functional
O'Hara	Phase/Task	Phase/Task
Petty	Phase/Task	Phase/Task
Phillippi	Phase/Task	Phase/Functional
Ramsey	Phase/Task	Task/Functional
Schmitt	Phase/Task	Total Only
Smith	Task/Subtask	Task/Functional

9. In response to the Request for Proposal, what format did the contractor use to present his cost proposal.

PROJECT ENGINEER	COST PROPOSAL FORMAT
Alexander	NO RESPONSE
Beachler	Milestone/Functional
Boensch	Phase
Couturier	NO RESPONSE
Hirsch	Task/Functional
Hojnacki	Task/Functional
Johnson	NO RESPONSE
Loptien	NO RESPONSE
O'Hara	NO RESPONSE
Petty	Task/Functional
Phillippi	Phase/Task/Functional
Ramsey	Phase/Functional
Schmitt	NO RESPONSE
Smith	NO RESPONSE

10. What was the process you went through to develop a WBS/SOW.

The answers to this question could not be placed into tabular form. The project engineers' responses are presented in a textual format.

Alexander- NO RESPONSE

Beachler- In common for all the phases, you usually start out with a goal in mind. I want to answer a question if it is a research study; or I want to develop a certain piece of hardware of a certain size if you are down in the hardware phase. You can usually then start to break the work down into step or what I call milestones. You can assign milestones to certain events you think are going to happen along the path to get to the product, whether it is a research answer or a piece of hardware. The next step is you can see that certain of these milestones are going to be more difficult to achieve than others in terms of time and dollars. You are going to incur certain costs associated with achieving those milestones.

In very broad terms /all our work/ is similar in that you start off with a question you want to answer or a problem to solve and a goal you want to achieve. You then have an approach and along that approach to get to the solution. But, I think each job, even though you may find a similar job to it, when you get down to the very specifics of writing a Statement of Work for it you have to tailor it to that job.

Boensch- Just exactly how do I visualize the work flow and how did I do it in the past? What is my objective and how do I see the program getting from A to B?

You must break the work down far enough to be meaningful in terms of managing a program. It is terribly application dependent and you can't just arbitarily say anything over a certain amount of money you will have a Work Breakdown Structure, or anthing under a certain amount of money you don't have it. I think you could do it by phase/task. You could use that approach as a Work Breakdown Structure, in that you break down the task. Now were discussing the level of breaking it down.

Couturier- You really can't go to a contractor and say these are the subtasks we want. Sometimes, depending on the process, the subtask may differ for each contractor. This means you cannot put that in the contract because your automatically cutting one of them out. You may not wat him cut out, because his process may be better. So, basically you have to hold up on some subtasks till you see which contractor you've got and he'll throw in that subtask.

Hirsch- NO RESPONSE

Hojnacki- NO RESPONSE

Johnson- NO RESPONSE

Loptien- NO RESPONSE

O'Hara- We solicit the contractor and usually suggest some alloy systems. Individual contractors like Pratt and Whitney

or General Electric give us their version of these alloy systems. Only the class of alloys is specified.

For example, I try to understand the process parameter that limits the process. How does this subsequently change the characteristics of the ingot? What I do is make ingots and analyze them. I analyze the results and eliminate the obvious systems that don't work or changes the parameters. Based on what we learn, we do another iteration and maybe even a third, and thus keep narrowing it down. This would be the tasks. Try to get an understanding of the important parameters. Then what I would do in phase 2 is do a modest scale up to demonstrate that I do understand the process; or I do have an alloy with the required mechanical properties of an alloy development program. I would demonstrate the process on a reasonable size of material. I try to box in the problem in the initial iteration and narrow it down and keep doing it providing time and money.

Petty- NO RESPONSE

Phillippi- I have the job tc be done clearly in mind before I start writing. I have also thought how I would do the job. So, I have a plan of action in mind of how I would do the job, but I would not want to constrain the contractor because he might have a better idea than I do. I structure the Statement of Work around the tasks or phases I would go through. Some Statements of Work are very clear in my mind and I'm very explicit about what I want done. Others are much more

researchy and therefore I don't want to box the contractor in. Therefore, I give the contractor a great deal of latitude. So, I tailor the type and range to the nature of the job.

Ramsey- NO RESPONSE

Schmitt- It occurs to me that how much you use a phase/task breakout or how it's structured depends upon the type of development being done. For instance, if it is a rather mature kind of development where there is quite a bit of background, but you are still extending the capability of the material, you may not exactly need the same kind of phase structure as you would if it were a brand new technology; where in fact you might build in decision points as to whether you want to continue. We are dealing in uncharted waters so to speak. If it's an area where there is a good foundation we would lay out a number of tasks because we know what needs to be done there. Yet, we don't have to build in a phase structure where we get to a point and have to decide whether we want to go any further. I think it depends, to a degree, on that kind of situation. On the other hand it it is an area where we are really exploring new ground so to speak, then very often you build a phase design into the way you structure the work statement and the way you put the program together. I would say the task/phase is very common. The Statement of Work, in general, tends to be fairly detailed in terms of the task breakout.

In priority it's dictated by experience. In other words, what has proven more or less successful in the past in programs, in terms of how you might phase it or break it out. I guess the way we do our programs here in the lab, in terms of content of individual programs, tend to develop over some fairly likely period of time. We put together the elements of a program in terms of objective and approach, what the pay offs are going to be, and the background that justifies the need for the program. That may be done up to a year before you actually start the program. The justification time is just inherent in the way we do the process. This gives time for data gathering in terms of background and what is going to feed into the program. Finally, you sit down and decide what the individual elements are going to be. Now that may be done individually or with others depending upon the area, whose working the project, and the nature of things. It has been my experience though that it has pretty much been an individual process. It is uncommon to get a large number of substative comments back about a particular Statement of Work you put together. In some sense it is an iterative process were you draft out the thing and put in a certain task. People will give some input about testing you have not included or some aspect of the thing that should be considered in terms of how you go about deciding how to break out the structure in terms of tasks and phases. I can't say there is any one rule of thumb or procedure that I personally use

or that other people use. It could be you had one in the past that was pretty satisfactory; you may in a sense copy it. Obviously changing it where it needs to be.

Smith- NO RESPONSE

11. What do you feel are the primary factors to be considered when developing a WBS/SOW?

Alexander- Try to break the Statement of Work out into items you think are going to be units of work.

Beachler- Level of Effort is normally the thing you look for when you go into the initial research or study. About all you can expect is to outline the work and to give your best shot to get some answers. In the intermittent phase you are starting to see products, either too small and not powerful enough for direct application to the final goal. So, during that phase you may not buy any hardware, but you are buying studies which are more then just Level of Effort. You want a piece of hardware of a certain size developed by the end of the program. You may or may not use that piece of hardware, but you want the research it takes to get you there. In the next phase you buy the hardware the size you want to use. That is where you are looking for the hardware product at the end, which may not take as much development as the other two phases on the part of the contractor. It may take more production type effort and some final touches on the research.

Boensch- How much information do you really need I think is the absolute key to developing a useful Work Breakdown Structure. You can either over whelm yourself with data and become lost in level four, five or six work packages or you can have a Work Breakdown Structure so course that it is vir-

tually useless. So you have to sit down and make consious decisions about the information you want. If someone came to me and said, "I want to make a Work Breakdown Structure what should I do?" I'd say, "Make damn sure you get enough data to know what is going on with the contract, but don't get so much data you get swamped. It could cost you."

Couturier- NO RESPONSE

Hirsch- You must write a program to stay within the funding limits.

Hojnacki- NO RESPONSE

Johnson- NO RESPONSE

Loptien- NO RESPONSE

O'Hara- NO RESPONSE

Petty- Try to scale the job to match the money available. Once I have a clear understanding of the amount of money I've got, then I try to scope the Statement of Work to come out even. The next consideration is how mature is the technology. How many companies out there can perform and what is their state of development.

Phillippi- NO RESPONSE

Ramsey- In exploratory development you are investigating items that very clearly have military application. It is not researchy like pure research. Often time it is difficult to associate pure research with a military application. In 6.2 you are looking at development of structual concepts involving advancements that have been made in materials, design,

fabrication, and demonstration of new concepts that have been developed. In exploratory development you are usually developing and demonstrating a concept or design that has military application and you are determining the pay off from the development or new concept. Payoffs, of course, are in terms of systems application: could weight be decreasing in a system, decrease cost hopefully Life Cycle Cost, longer range, enhanced maintainability of the structure. The level on which we demonstrate new concepts is on a component level.

Schmitt- NO RESPONSE

Smith- NO RESPONSE

12. What sources did you use while developing a WBS/SOW.

PROJECT ENGINEER	SOURCES
Alexander	No particular sources
Beachler	Other SOW
Boensch	Master planning documents, other SOW & WBS, prior contracts, on-going contracts
Couturtier	Other SOW
Hirsch	NO RESPONSE
Hojnacki	NO RESPONSE
Johnson	Other SOW/Fellow engineers
Loptien	NO RESPONSE
O'Hara	NO RESPONSE
Petty	Contract Managers Handbook/Individuals such as staff and engineers/past SOW/ Potential contractors
Phillippi	Uses no previous references
Ramsey	NO RESPONSE
SCHMITT	NO RESPONSE
SMITH	NO RESPONSE

APPENDIX C

SAMPLE STATEMENTS OF WORK

EXHIBIT C-1

SAMPLE STATEMENT OF WORK
CONTRACT F33615-81-C-1546

INTEGRATED NAVIGATION SYSTEM SIMULATION

1.0 INTRODUCTION (OBJECTIVE):

There are two specific objectives for this program. The first objective is to develop and test algorithms and control logic that integrates and controls the communication/navigation/identification (CNI), and antenna functions. This software should produce an integrated navigation system whose capabilities exceeds that of each function alone, when operating in the tactical environment envisioned for the 1990's. Two sets of algorithms and logic will be developed and tested to form two baselines. The first set will encompass a relatively limited integration; the second set will be much less constrained to pursue maximum integration. From these two sets, integration techniques and performance assessments will be established to provide the government risk reduction and a knowledge base for any future integration efforts. The second objective is to look at system design issues, via analysis and detailed simulations, for the antenna designs developed under the concurrent Adaptive Multifunction Antenna (AMA) Program as well as the receiver designs developed under the ICNIA System Definition Program. From this, the INSS Program will provide detailed design data concerning antenna, receiver, and algorithm evaluation performance. Through interrelationships with other programs, it is hoped that effective system integration can be accomplished during the design phase, rather than after equipment has been produced.

2.0 SCOPE:

The INSS Program is divided in two phases: the GPS/JTIDS/IFF phase and the Communication/Navigation/Identification (CNI) phase. During the GPS/JTIDS/IFF phase, the contractor shall develop, test, and evaluate integrated navigation algorithms and control logic that have limited inputs, outputs, and control variables. This shall be accomplished via detailed computer simulations of antenna, receivers, and inertial equipments set in environment scenarios envisioned for the [illegible]'s. From these simulations, the contractor will determine the algorith[illegible] [illegible]ogic effects on navigation, communication, and identification. In addition, the INSS contractor will test and evaluate the AMA's GPS/JTIDS/IFF antenna designs for detailed system interface issues as well as system level navigation, communications, and identification performance. The contractor will provide this data, along with his recommendations, to the AMA contractor.

During the CNI phase, the contractor will modify and develop the algorithms/logic for more thorough system integration. Interface state variables will be limited by the AMA's CNI designs and the Integrated CNI Avionics (ICNIA) designs, but the INSS contractor should have a role in determining these limitations. In conjunction with developing, testing, and evaluating the CNI integrated navigation algorithms/logic, the contractor shall test and evaluate the AMA's CNI antenna designs and ICNIA designs for detailed system interface issues, as well as system level navigation, communication, and identification performance. As before, detailed computer simulations shall be used. From these tests and evaluations, the contractor will provide the AMA and ICNIA contractors with design data and recommendations.

3.0 GENERAL BACKGROUND:

Several related programs are applicable as referenced for the INSS Program. The following is a synopsis of these programs. In addition to the programs

mentioned herein, several other sources of information are available to expand the technical base required for this effort.

3.1 GPS/JTIDS Threat Study: In Avionics Laboratory Contract F33615-78-C-1563 with the Charles Stark Draper Laboratory (CSDL), an effort was undertaken Aug 79 to define the GPS/JTIDS threat for the late 1980's and 1990's. This threat model is not intended to be a "validated" threat model, but is intended to provide an initial threat definition.

3.2 GPS/JTIDS/Inertial Navigation System (INS) Operational Impact Analysis: In an Avionics Laboratory sponsored segment of Space Division (SD) Contract F04701-79-C-0030 with The Analytic Sciences Corporation (TASC), an effort was undertaken Feb 80 to develop a set of tactical mission scenarios appropriate for integrated GPS/JTIDS/INS systems in the late 1980's and 1990's which:

(a) define mission profiles;

(b) define required navigation and communication performance for each mission segment;

(c) define the threat environment for each mission segment;

(d) allocate performance requirements to the GPS/JTIDS Adaptive Multi-function Antenna (AMA) level.

The mission scenarios resulting from this effort are not intended to be "validated" mission scenarios for the late 1980's and 1990's, but are intended to provide an initial definition of the environment and the performance required for the integrated system.

3.3 CNI Operational Impact Analysis II: The Avionics Laboratory is currently undertaking a CNI Operational Impact Analysis to develop the same mission scenario and CNI performance requirements for integrated CNI systems and CNI AMA's of the 1990's as is described in the GPS/JTIDS/INS Operational Impact Analysis effort above.

3.4 Multi-Function Multi-Band Airborne Radio System (MFBARS): In Avionics Laboratory Contracts F33615-78-C-1518 and F33615-77-C-1172 with ITT and TRW, preliminary design and architecture studies were undertaken addressing adaptive multi-function antennas and their impact on integrated CNI avionics systems.

3.5 GPS Phase IIB Full Scale Development: In SD Contracts F04701-79-C-0083 and F04701-79-C-0085 with Rockwell International Collins and Magnavox, GPS Engineering Development Model (EDM) equipment is under development for the F-16 applications.

3.6 JTIDS Full Scale Development: ESD is currently contracting for full scale development of JTIDS Class II terminals for the F-16 application. A single award is anticipated for development of this JTIDS equipment.

3.7 Integrated CNI Avionics: The Avionics Laboratory is planning to undertake initial development of an Integrated CNI Avionics (ICNIA) system which would utilize adaptive antennas as a critical source of anti-jam performance. It is

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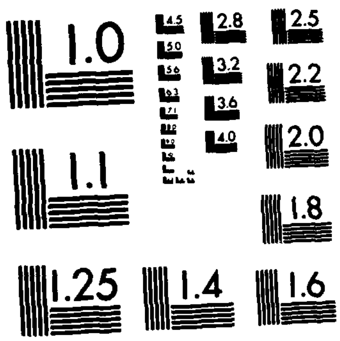

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anticipated the ICNIA System Definition Program will be a dual-award program conducted in parallel with the Integrated Navigation System Simulation (INSS) Program. It is intended that the contractor will contribute greatly in the ICNIA design development.

3.8 Adaptive Multifunction Antenna (AMA): The Avionics Laboratory is currently contracting to develop the technology necessary to produce an adaptive antenna that integrates the CNI functions, i.e., inertial, GPS, JTIDS, SEEK TALK, SINCGARS, and IFF. The AMA Program will be closely associated with INSS to provide mutual benefit and aiding in achieving program goals. The first phase of AMA (CNI AMA I) will integrate INS, GPS, JTIDS, and IFF functions into an adaptive antenna system. The second phase (CNI AMA II) will integrate all CNI functions. The AMA contractor will simulate and test his antenna designs. His simulations will be made available to the INSS contractor for INSS use. In turn, the INSS contractor will evaluate the antenna designs and provide evaluation data and recommendations to the AMA contractor. The AMA contract is anticipated to be dual award with competition for initial design, reverting to a single award to completion.

3.9 Agile Bandpass Filter Technology Validation: The Avionics Laboratory, Contract F33615-80-C-1109, effort is being undertaken to develop an Agile Bandpass Filter (ABF) and to validate the CNI enabling technology identified under the MPBARS Program. It is anticipated this technology will be applicable to the CNI design.

4.0 TASKS/GENERAL REQUIREMENTS:

4.1 Phase I

4.1.1 Task 1 - Preliminary Integrated Navigation Algorithms/Logic Design:

The thrust of this task is to develop a preliminary design of software that will both integrate GPS, JTIDS, IFF, INS, and antenna equipments, and exploit synergistic benefits available through integration. System requirements and limitations will be defined; methods and philosophy of integration will be determined; and a framework for integrated navigation algorithms/logic (to be developed under Task 4) will be designed for the definitions of the environment envisioned for the integrated navigation system. The first goal of this task is to design integrated navigation algorithms/logic that achieve maximum navigational performance with no adverse impact to the communications and identification functions. Although increase in navigational accuracy is a desired (and expected) result, primary emphasis should be given to increasing system tolerance of dynamics, electronic countermeasures, and self induced interference. This algorithm/logic design will establish a performance baseline for "simple" integration with as little impact to the GPS, JTIDS and Mark XII IFF equipment designs as possible.

4.1.1.1 The contractor shall develop a preliminary design of the integrated navigation algorithms/logic. He shall insure that the design is compatible with the GPS Phase IIB EDM equipment designs, the JTIDS Class II terminal equipment design, the Mark XII IFF specifications, and the CNI AMA I antenna designs. In addition, he shall develop a set of performance goals to measure and compare the integrated navigation algorithms/logic designs during development (Task 4).

4.1.1.2 The contractor shall present the preliminary design to the government at the first PDR. At this review, he shall delineate:

a) limitations imposed by equipment designs;

b) the software's input, output, and control variables;

c) chosen methods/philosophy for integration;

d) locations and methods for obtaining access to the input, output, and control variables from the equipments that are being integrated;

e) hierarchial structure of the proposed integrated navigation algorithms/logic;

f) functional description of each part in the hierarchial structure;

g) interface requirements between functional parts;

h) preliminary performance goals for the GPS/JTIDS/IFF integrated algorithms/logic and the integrated system.

4.1.2 <u>Task 2 - Simulated Test System Design</u>:

The integrated navigation algorithms/logic designed under this program must be tested for adequacy and to establish a performance baseline. In addition, the designs must be demonstrated against a realistic type of environment to determine system flaws, characteristics, and strengths which may not be evident in simplified, controlled tests. Therefore, a comprehensive set of Monte Carlo simulations are envisioned for this purpose. In this task the contractor shall design the Simulated Test System (STS) - all computer software which will be used as evalution tools for the GPS/JTIDS/IFF integrated navigation algorithm/logic designs. This includes the simulations of INS, receivers, scenarios, algorithms/logic, and antennas. In addition, the STS will be used to test and evaluate the CNI AMA I antenna designs produced by the AMA contractor for system level communication, navigation, and identification performance as affected by integration design issues.

4.1.2.1 The contractor shall design the STS. He shall insure that the designed STS can test algorithm/logic and antenna designs:

a) when integrated with GPS Phase IIB, Mark XII IFF, and JTIDS Class II engineering development model equipments;

b) against hostile electronic countermeasures designed for the GPS/JTIDS/IFF/INS/antenna integrated system;

c) for tactical fighter-type dynamics effects;

d) for dynamic airframe masking effects;

e) for antenna/receiver interface effects;

f) at various levels of complexity, as required for algorithm/logic development and antenna design analysis;

g) for self-induced interference effects;

h) for system performance against representative tactical missions; and to fulfill requirements of paragraph 4.1.3.1.

The contractor shall present the STS design to the government for approval at the first PDR. In addition to fulfilling the MIL STD 1521 requirements, the contractor shall describe how the STS design fulfills the above objectives.

4.1.2.2 The contractor shall develop up to six mission scenarios for use in the STS. He shall design these scenarios for the GPS/JTIDS/IFF requirements envisioned for the 1990's. He shall consider the results of the GPS/JTIDS/INS Operational Impact Analysis, GPS/JTIDS threat study, and CNI Ops Impact Analysis II programs. The contractor shall insure that the developed scenarios can test the CNI AMA I antenna designs and the algorithm/logic designs of Task 4. He shall present the scenarios to the government for approval at the first quarterly progress review.

4.1.2.3 The contractor shall develop models of the Mark XII IFF, GPS Phase IIB, and the JTIDS Class II terminal engineering development (EDM) equipments for use in the STS. This effort shall encompass the two GPS Phase IIB receiver equipments, two Mark XII IFF equipments, and one JTIDS Class II terminal equipment. The contractor shall obtain equipment information sufficient to realistically simulate equipment operations and characteristics as influenced by the environment; as well as each receiver's effects on the GPS/JTIDS/IFF algorithm/logic and antenna designs. In the event specific information cannot be obtained, the contractor shall make reasonable assumptions and document those assumptions at quarterly progress reviews. The contractor shall present final receiver models to the government for modification and/or approval no later than the sixth quarterly progress review. As required, the contractor shall modify final receiver models to reflect pertinent receiver design changes (until the seventh quarterly progress review).

4.1.3 Task 3 - STS Development:

This task is primarily concerned with developing the STS and encoding all software. Data items are required for tracking the software development, transferring the STS to government computer facilities, and describing the STS for future evolution and use. Since the STS is the major test vehicle by which the integrated navigation algorithms/logic and the AMA's adaptive antenna designs are tested, this task must demonstrate the STS's validity. The contractor shall document the STS in accordance with Seq #13, DD Form 1423, Atch #1.

4.1.3.1 The contractor shall develop the STS. He shall use the "American National Standard Programming Language, FORTRAN, X3.9-1978" referred to as "FORTRAN 77" for encoding all software. He shall provide listings of all

software in accordance with Sequence #2, DD 1423, Atch #2. The contractor shall structure the STS such that scenario data necessary to exercise the designed integrated navigation algorithms/logic via the GPS Evaluator PDP 1170 facility at the Avionics Laboratory are output to a magnetic tape. He shall provide the government with an interface specification in accordance with sequence 11, DD 1423, Atch #1. The STS shall be suitable for installation on the Wright-Patterson AFB CDC Computer Facility.

4.1.3.2 The contractor shall review the CNI AMA I antenna simulations. If any simulation errors are found which may adversely impact the AMA simulation results, the INSS contractor shall immediately notify the government's project manager. From the AMA's simulations, technical interchanges, and quarterly progress reviews; the contractor shall design antenna simulations or modify the AMA antenna simulations for STS use. In either case, he shall insure that these antenna simulations, which form a part of the STS, adequately model and simulate each CNI AMA I antenna design and fulfills STS requirements as outlined in para. 4.1.2.1. The contractor shall update these simulations as necessary to reflect design changes incorporated by the AMA contractors.

4.1.3.3 The contractor shall develop a simple omni antenna simulation which includes aircraft backlobe suppression effects. This simulation shall be used to establish a baseline performance for AMA antenna performance assessments.

4.1.3.4 The contractor shall design tests to verify the validity of the STS's functional modules, such as inertial, receiver, antenna, etc., as well as tests to verify the STS as a whole. He shall present these tests and their results to the government no later than the start of Task 6.

4.1.4 <u>Task 4 - GPS/JTIDS/IFF Integrated Navigation Algorithms/Logic Development</u>: The contractor shall document the Algorithms/logic developed under this task in accordance with Seq #17 & #18, DD Form 1423, Atch #1.

4.1.4.1 The contractor shall design and develop detailed GPS/JTIDS/IFF integrated navigation algorithms which shall combine GPS, JTIDS, and inertial navigation information in an optimal sense to maximize navigational performance without sacrifice to communication or identification performance. The contractor shall design these algorithms to integrate and interface with the GPS Phase IIB receivers, the JTIDS Class II terminal, inertial navigation systems, Mark XII IFF, and the CNI AMA I antenna designed for these receivers. With the limitations imposed by these equipment designs, the contractor shall design and develop controlling logic that will monitor the environment, select and edit information resources, and control the combined system to maximize performance during hostile conditions (to include, as a minimum, dynamics; enemy electronic countermeasures; and self-induced interference).

4.1.4.2 The contractor shall record the mathematical derivations of algorithms/logic. He shall provide the detailed derivations to the government at the quarterly progress review subsequent to the derivation. In addition, he shall present the algorithms/logic and a synopsis of the derivation at said quarterly progress reviews.

4.1.4.3 The contractor shall encode the algorithm/logic in Fortran 77 to form a part of the STS.

4.1.5 Task 5 - GPS/JTIDS/IFF Trade-Off Studies and Design Recommendations:

The purpose of this task is to test and evaluate the AMA GPS/JTIDS/IFF antenna designs and the GPS/JTIDS/IFF algorithm/logic designs of Task 4 to provide direction for successive design iterations. The contractor shall accomplish final evaluation of the designs via the detailed Monte Carlo environment/mission simulations in Task 6. However, in this task, special excerpts, static tests, etc., should be used to screen those problem areas evident in less comprehensive and less costly tests.

4.1.5.1 The contractor shall design and perform trade-off studies using parts of the STS to test the design of the GPS/JTIDS/IFF integrated navigation algorithms and controlling logic as well as the CNI AMA I antenna designs. He shall present proposed test objectives and methods of accomplishment for the subsequent three months at each of the second through sixth quarterly progress reviews. In addition, the contractor shall present changes to the proposed objectives or methods and the results of tests run during the previous three months at the third through seventh quarterly progress reviews.

4.1.5.2 The contractor shall analyze the test data to evaluate the CNI AMA I antenna designs and the GPS/JTIDS/IFF integrated navigation algorithms/controlling logic; and determine design weaknesses, flaws, or oversights which decrease maximum performance. From this, he shall make recommendations for design improvement for the CNI AMA I antenna via Task 11. He shall document the data and recommendations in accordance with Seq #16, DD Form 1423, Atch #1.

4.1.6 Task 6 - GPS/JTIDS/IFF Performance Evaluation and System Specification:

4.1.6.1 The contractor shall develop a set of test plans for performing final system evaluations of: 1) the GPS/JTIDS/IFF integrated navigation algorithms/logic; 2) the CNI AMA I antenna, and 3) the integrated GPS/JTIDS/INS /IFF antenna system composed of GPS Phase IIB user equipment designs, JTIDS Class II terminal equipments designs, CNI AMA I antenna design, inertial navigation, Mark XII IFF, and the GPS/JTIDS/IFF integrated navigation algorithms/logic.

4.1.6.2 The contractor shall present the set of test plans to the government prior to use. At the presentation, he shall delineate:

a) the STS outputs to be recorded;

b) the criteria to be used for measuring system performance;

c) the methods to be used for evaluating system performance.

4.1.6.3 After presenting the set of test plans to the government, the contractor shall:

a) perform the final system evaluation of the GPS/JTIDS/IFF integrated navigation algorithms/logic;

b) perform the final system evaluation of the CNI AMA I antenna;

c) perform the final system evaluation of the integrated IFF/GPS/JTIDS/INS/antenna system for both omni and CNI AMA I antennas;

d) develop specifications for the GPS/JTIDS/IFF integrated navigation algorithms/logic in accordance with Sequence #11, DD 1423, Atch #1.

4.2 Phase II

4.2.1 Task 7 - CNI Algorithms/Logic Development:

The purpose of this task is to develop integrated navigation algorithms/logic designed to perform "total" integration. These algorithms/logic will be used to establish a performance baseline for complex integration techniques. This baseline and the one established under Phase I will enable government planners to trade off performance, complexity, and cost considerations in future integration efforts. The contractor shall document the algorithms/logic developed under this task in accordance with Seq # 17 & #18, DD Form 1423, Atch #1.

4.2.1.1 The contractor shall determine algorithms/logic limitations imposed by the ICNIA receiver designs and the CNI AMA II antenna designs. He shall determine modifications to these limitations which would improve algorithm/logic performance for the integrated system's design. The contractor shall relate these modifications to the ICNIA and AMA contractors via Task 11 for possible inclusion in the ICNIA and AMA designs.

4.2.1.2 The contractor shall develop a preliminary design of the CNI algorithm/logic. He shall develop a set of performance goals to measure and compare the CNI algorithm/logic designs during development. The contractor shall present the preliminary design to the government at the second PDR. At this review he shall present:

a) the software's input, output, and control variables;

b) chosen methods/philosophy for integration;

c) hierarchial structures of the proposed integrated navigation algorithms/logic;

d) functional description of each part in each hierarchial structure;

e) interface requirements between structural parts;

f) preliminary performance goals for the CNI algorithm/logic and the integrated system.

4.2.1.3 The contractor shall modify and develop the CNI algorithms/logic for application to the ICNIA receiver designs and the CNI

AMA II antenna designs. The contractor shall develop these algorithms/logic to integrate ICNIA receiver and AMA antenna capabilities for maximum navigational performance during a highly dynamic, hostile mission without sacrifice to the communication and identification functions.

4.2.1.4 The Contractor shall record the mathematical derivations of CNI algorithms/logic. He shall provide the detailed derivations to the Government at the quarterly progress review subsequent to the derivation. In addition, he shall present the CNI algorithms/logic and a synopsis of the derivation at said quarterly progress review.

4.2.2 Task 8 - STS Modification:

To effectively develop, test, and evaluate the CNI algorithms/logic, and test and evaluate the AMA and ICNIA designs, the STS must be modified to include additional communication functions. This task encompasses STS modification. The contractor shall document the modified STS in accordance with Seq. #13, DD Form 1423, Atch #1.

4.2.2.1 The contractor shall review the CNI Operational Impact Analysis II scenarios and modify or develop, as necessary, up to six scenarios for testing the AMA's CNI II antenna designs, the ICNIA designs, and the CNI algorithms/logic designs. He shall present the scenarios to the government for approval by the fourth quarterly progress review.

4.2.2.2 The contractor shall review the ICNIA receiver simulations. If any simulation errors are found which may adversely impact the ICNIA simulations results, he shall immediately notify the government's project manager. The contractor shall design receiver simulations or modify the ICNIA's simulations to emulate the ICNIA receiver designs. Where ICNIA design information is insufficient, the contractor shall make reasonable design assumptions and document those assumptions at the subsequent quarterly progress review. He shall modify the simulations, as necessary, to reflect any design changes incorporated by the ICNIA contractors.

4.2.2.3 The contractor shall modify the STS. He shall insure that the modified STS can test CNI algorithm/logic, antenna, and receiver designs:

a) for antenna/receiver interface effects;

b) against hostile electronic countermeasures designed for the integrated CNI system;

c) for tactical fighter-type dynamics effects;

d) for dynamic airframe masking effects;

e) at various levels of complexity, as required, for algorithm/logic development, antenna design analysis, and receiver design analysis;

f) for self-induced interference effects;

g) for system performance against representative scenarios.

In addition, the contractor shall structure the STS modification such that scenario data necessary to exercise the designed integrated navigation algorithms/logic via the GPS Evaluator PDP 1170 facility at the Avionics Laboratory are output to a magnetic tape. He shall provide an interface specification in accordance with sequence 11, DD1423, Atch #1. The contractor shall present the modified STS design to the government at the second PDR and delineate how the design meets the above objectives. The STS shall be suitable for installation on the Wright-Patterson AFB CDC Computer Facility.

4.2.2.4 The contractor shall review the CNI AMA II antenna simulations. If any simulation errors are found which may adversely impact AMA simulation results, the contractor shall immediately notify the government's project engineers. From the AMA's simulations, technical interchanges, and quarterly progress reviews, he shall design antenna simulations or modify the AMA's antenna simulations for STS use. In either case, the contractor shall insure that the antenna simulations which form a part of the STS adequately model and simulate the CNI AMA II designs and fulfills STS requirements as outlined in para 4.2.2.3. In addition, he shall update these simulations as necessary to reflect any design changes incorporated by the AMA contractor.

4.2.2.5 The contractor shall design tests to verify the validity of functional modules, such as inertial, antenna, receiver, etc., as well as tests to verify the STS as a whole. He shall present these tests and their results to the government no later than the quarterly review following test completion.

4.2.3 Task 9 - CNI Trade-Off Studies and Design Recommendations:

The purpose of this task is to test and evaluate the CNI AMA II antenna designs, the ICNIA designs, and the CNI algorithms and logic designs to provide direction for successive design iterations. The contractor shall accomplish final evaluation of the designs via the detailed Monte Carlo environment/mission simulations in Task 10. However, in this task, special excerpts, static tests, etc., should be used first to screen those problem areas evident in less comprehensive and less costly tests.

4.2.3.1 The contractor shall design and perform trade-off studies to test the performance of those integrated navigation algorithms and controlling logic designed in Task 8, as well as the ICNIA designs and the CNI AMA II antenna designs. He shall present proposed test objectives and methods of accomplishment for the subsequent three months at each of the fourth through ninth quarterly progress reviews. In addition, the contractor shall present changes to the proposed objectives or methods and the results of tests run during the previous three months at the fifth through tenth quarterly progress reviews.

4.2.3.2 The contractor shall analyze the test data to evaluate the CNI AMA II antenna designs, the ICNIA designs, and the CNI algorithms/ logic; and determine design weaknesses, flaws, or oversights which decrease maximum system performance. From this, he shall provide test data and make recommendations for design improvements for the ICNIA receiver and the CNI AMA II antenna via Task 11. The contractor shall document the data and recommendations in accordance wtih Seq #16, DD Form 1423, Atch #1.

4.2.4 Task 10 - CNI Performance Evaluation/System Specification:

4.2.4.1 The contractor shall develop a set of test plans for performing final system evaluations of: 1) the CNI algorithms/logic; 2) the CNI AMA II antenna design; 3) the ICNIA designs; and 4) the integrated system.

4.2.4.2 The contractor shall present the set of test plans to the government prior to use. At the presentation, he shall delineate;

a) the STS outputs to be recorded;
b) the methods to be used for evaluating system performance;
c) the criteria to be used for measuring system performance.

4.2.4.3 After presenting the set of test plans to the government, the contractor shall perform the final system evaluations of and determine performance capabilities of:

a) the CNI AMA II antenna;
b) the ICNIA designs;
c) the integrated system using omni antennas;
d) the integrated system using the CNI AMA II antenna;
e) the CNI algorithms/logic;

and he shall develop specifications for the CNI algorithms/logic in accordance with Sequence #11, DD 1423, Atch #1.

4.3 Tasks Common to Both Phases

4.3.1 Task 11 - Technical Interchange:

Technical Interchange with the AMA contractor, the ICNIA contractors, and the Agile Bandpass Filter contractor will be chaired by the Avionics Laboratory with participation by the contractors involved. Final decision authority rests with the government. The purpose of this periodic technical interchange is to:

a) exchange technical information to minimize duplication of technical effort;
b) maintain design compatibility with developing equipment designs;
c) insure the accuracy of the simulations.

The contractor shall provide the manpower, data, travel support, and material resources required to support technical interchanges:

a) quarterly with up to two AMA contractors for three quarters and one AMA contractor for seven additional quarters (unidentified);
b) quarterly during Phase 1 with two GPS EDM equipment contractors (Collins and Magnavox);
c) quarterly during Phase 1 with one JTIDS EDM equipment contractor (unidentified);
d) as necessary with the two Mark XII IFF Contractors (Teledyne & Hazeltine)
e) quarterly with two ICNIA contractors (unidentified);
f) twice with one Agile Bandpass Filter contractor (Rockwell International).

The contractor shall document working group meetings in accordance with Seq #[illegible] & #15, DD Form 1423, Atch #1.

4.3.1.1 The contractor shall interchange with the AMA contractors to support development of:

a) mission scenarios;

b) navigation, communication, and identification performance requirements;

c) threat environment models;

d) antenna simulations;

and to exchange evaluation data and simulation results to improve the antenna/algorithm designs. For planning purposes, it is estimated that nine working group meetings and one informal technical interchange (via telephone or written correspondence) will be conducted with one AMA contractor, and three working group meetings will be conducted with another AMA contractor. For each meeting, the contractor shall prepare information for technical exchange of ideas, needs, and results. The contractor shall address any action items stemming from the meetings through the minutes, Sequence #[illegible], DD 1423, Atch #1, and follow-up letters (if follow-ups are necessary).

4.3.1.2 The contractor shall conduct technical interchanges with the GPS and JTIDS EDM contractors quarterly for the duration of Phase I to support the development and coordination of analysis and simulations of the GPS and JTIDS [illegible] equipments. He shall conduct eight technical interchanges with each of the GPS and JTIDS EDM equipment contractors with additional technical interchanges scheduled as required by the contractor. For planning purposes it is estimated four working meetings and four informal technical interchanges (via telephone and written correspondence) will be conducted with each of the GPS and JTIDS EDM contractors. The contractor shall schedule these working group meetings to the extent possible in conjunction with scheduled progress and design reviews and AMA contractor technical interchange working group meetings.

4.3.1.3 The contractor shall conduct technical interchanges with the two MARK XII IFF contractors as required during Phase I to support the development and coordination of analysis and simulations of the MARK XII equipment. The contractor shall coordinate with the AMA contractors to the extent possible to schedule these technical interchange working group meetings in conjunction with scheduled progress and design reviews and AMA technical interchange working group meetings.

4.3.1.4 The contractor shall conduct technical interchange with the two ICNIA contractors quarterly to support the development and coordination of analysis and simulations of the two ICNIA equipments. He shall conduct seven technical interchanges with each of the two ICNIA equipment contractors with additional technical interchanges scheduled as required by the contractor. For planning purposes it is estimated four working group meetings and three informal technical interchanges (via telephone and written correspondence) will be conducted with each of the two ICNIA equipment contractors. The contractor shall schedule the working group meetings [illegible]

4.3.1.5 The contractor shall conduct technical interchange with the Agile Bandpass Filter contractor twice (or until all efforts are completed) to support:

(a) evaluation of the Agile Bandpass Filter technology for impacts to the algorithm/logic design:

(b) ICNIA simulation efforts.

For planning purposes he shall conduct two technical interchange working group meetings with the Agile Bandpass Filter contractor at WPAFB with additional technical interchanges scheduled as required by the contractor and approved by the government.

4.3.2 Task 12 Program Cost Management

4.3.2.1 The contractor shall implement an effective program cost management and control structure to assure that each task of this Statement of Work is accomplished as specified, on time, and within the budgeted funds. He shall develop and maintain the Contract Work Breakdown Structure (CWBS) and dictionary in compliance with the concepts set forth in MIL-STD-881A.

The contractor shall use the CWBS as the primary framework for contract planning, budgeting, and reporting cost and schedule status to the government. He shall maintain and update the CWBS during the execution of the contract in accordance with Sequence #10, DD 1423, Atch #1. He shall insure that financial/cost reporting references applicable CWBS elements and be in accordance with the requirements of Sequence #12 and #14, DD 1423, Atch #1.

4.3.2.2 The contractor shall designate a program manager who shall be responsible for the technical and financial management of this contract. The program manager shall maintain a close liaison with the government's project manager, or designee, via weekly telephone conversations.

4.3.3 Task 13 Computer Usage

4.3.3.1 The contractor shall provide the computer facilities, resources, and processing time required to perform the effort required by this Statement of Work. He shall provide a computer facility having a SECRET NOFORN facility clearance for simulation of (1) the threat environments; (2) portions of the GPS and JTIDS EDM equipment designs; (3) portions of the ICNIA equipment design; (4) performance evaluations in the threat environments; and (5) other portions of this effort determined to be classified in accordance with the DD 254.

4.4 General Requirements:

The contractor shall adhere to the general requirements specified in subparagraphs hereto in conducting the tasks specified in paragraph 4.1, 4.2, 4.3, and subparagraphs thereto.

4.4.1 Design-to-Cost:

In the selection of a technical approach to achieve the GPS/JTIDS/IFF and CNI algorithms/logic design objectives, equal consideration shall be given to eventual life-cycle-cost as to the attainment of performance goals and requirements. The STS shall be designed for ease of modification and efficient application.

4.4.2 Responsibility For Tests:

The contractor shall be responsible for performance of the demonstrations, tests, and evaluations required by this contract. However, the government reserves the right to inspect, witness, or separately perform any of the tests specified. The contractor shall keep the government informed of the schedule of testing in order to allow observers to attend any tests.

5.0 REPORTS, DATA, AND OTHER DELIVERABLES:

5.1 Reports, Data:

The contractor shall prepare and provide reports and data in accordance with Atch #1, DD Form 1423.

5.2 Computer Programs:

The contractor shall prepare and provide computer programs in accordance with Atch #2, DD Form 1423.

5.3 Contract Cost Management System:

The contractor shall establish, use, and maintain an effective contract cost management system as specified in subparagraphs hereto. He shall document the walk through/talk through in accordance with Seq #3, #8 & #15, DD Form 1423, Atch #1

5.3.1 The contractor shall use a cost management system of the contractor's design for planning and controlling cost and for measuring contract performance (value for completed tasks). He shall provide at contract award a summary description of the cost management system which delineates how cost and performance information, to be reported under the C/SSR data item, will be derived.

5.3.2 In conjunction with the kickoff meeting, the contractor shall provide the Air Force Program Manager, or his designated representative, a talk through/walk through of the cost management system and methods used for generating cost and schedule information to be reported under the C/SSR data item. Once a mutual understanding is gained, the contractor shall (1) notify the procuring authority of changes to cost management procedures used during the contract, and (2) explain the new methods and reason for the changes. Authority for approval and use of the contractor's cost management system rests with the government.

5.4 Financial Reporting:

5.4.1 The contractor shall insure that financial reporting is in accordance with the CDRL and attachments thereto. He shall reference the applicable Contract Work Breakdown Structure (CWBS) elements on all financial reports. The contractor is encouraged to substitute internal reports for the C/SSR, provided data elements and definitions are comparable to those required in the government report.

5.4.2 The contractor shall, with the agreement of the Air Force Program Manager or his designated representative, place C/SSR requirement or other appropriate cost performance reporting requirements on subcontractors that:

(a) have critical prime contract technical tasks;

(b) have contracts of $2 million or more and are not firm-fixed price.

Critical tasks shall be defined by mutual agreement between the Air Force Program Manager (or his designee) and the prime contractor. The subcontractor's reported cost and schedule information shall be incorporated in the prime contractor's C/SSR.

5.4.3 A reconciliation by the contractor of C/SSR data elements with like elements in other financial reporting documents shall be accomplished as an addendum to the C/SSR when the documents are submitted for the same reporting period.

5.5 Contract Work Breakdown Structure:

5.5.1 The contractor shall maintain the CWBS and dictionary in compliance with the concepts set forth in MIL-STD-881. The negotiated CWBS shall establish the basis for further evolutionary extension by the contractor to lower levels during the performance of the contract.

5.5.2 The contractor shall use the CWBS as the primary framework for contract planning, budgeting, and reporting cost and schedule status to the government.

5.5.3 The contractor shall maintain and update the CWBS during the execution of the contract in accordance with Sequence #10, DD 1423, Atch #1.

5.5.4 During the performance of the contract, the contractor shall update the CWBS as additional program definition is accomplished, and propose alternatives for improvement. Authority for approval and use of such alternatives rests with the Air Force Program Manager or his designee.

5.6 Kickoff Meeting:

The contractor shall participate in a kickoff meeting at the Avionics Laboratory to discuss initial aspects and course of this program. At this meeting, the contractor shall present the overall management structure to be used for this program and a detailed briefing on the control procedures to be used. Based on the requirements of this program, the contractor shall also present (1) a detailed schedule and work breakdown structure (WBS) of the efforts to be completed under this program; and (2) the cost management and control structure to assure that each task under this program is accomplished as specified, on-time, and for the budgeted funds. He shall document

this meeting in accordance with Seq #3, #8 & # 15, DD Form 1423, Atch #1

5.7 Reviews:

The contractor shall conduct the following Program Reviews. The contractor shall allow the GPS Phase I'R, JTIDS Class II terminal, MARK XII IFF, AMA, ICNIA, Agile Bandpass Filter, and other Independent Analysis contractors to participate in the technical portion of each program review as requested and approved by the government. He shall document the review in accordance with Seq 3, 8, $ 15, DD Form 1423, Atch #1.

5.7.1 Program Reviews:

The contractor shall hold quarterly progress reviews at his facility, at the Avionics Laboratory, and at other facilities determined by the government to review program progress to date, problem areas, and future course of the program. For planning purposes it is estimated six of the quarterly progress reviews will be held at the AMA contractor's facility, three will be held at the Avionics Laboratory, and one at his facility. The quarterly progress reviews shall be held in conjunction with schedule design reviews to the extent possible.

5.7.2 Preliminary Design Review (PDR):

The contractor shall conduct two PDR's. For planning purposes, the first PDR shall be held at his facility and the second PDR shall be held at the Avionics Laboratory. The reviews shall be conducted in accordance with applicable requirements of MIL-STD-1521 (USAF).

5.8 Presentations to Government and Industry:

The contractor shall prepare and present two briefings to Government and Industry. In the first briefing the contractor shall report the accomplishments, conclusions, and recommendations of Tasks 1 through 6. In the second briefing he shall report the accomplishments, conclusions, and recommendations of Tasks 7 through 10. The government shall have the option to review (at the contractor's facility) each briefing at least ten days prior to the scheduled briefing date to make changes and/or approve the briefing. The contractor shall insure that neither briefing is longer than six hours of presentation. The contractor shall provide unclassified presentation material at the briefings in accordance with Sequence #3, and #8, DD Form 1423, Atch #1.

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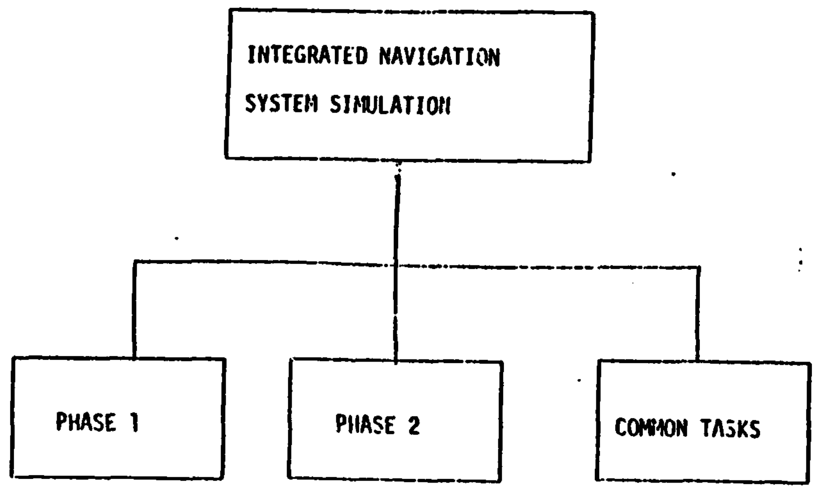
INTEGRATED NAVIGATION SYSTEM SIMULATION
CONTRACT WORK BREAKDOWN STRUCTURE

LEVEL 1

LEVEL 2



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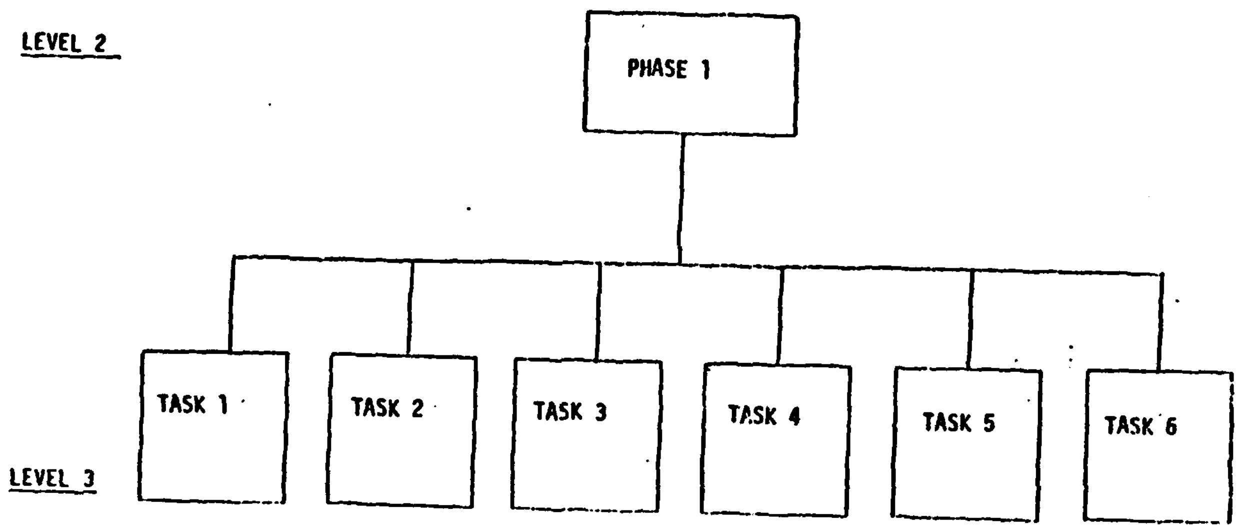
CONTRACT WORK BREAKDOWN STRUCTURE
PHASE 1



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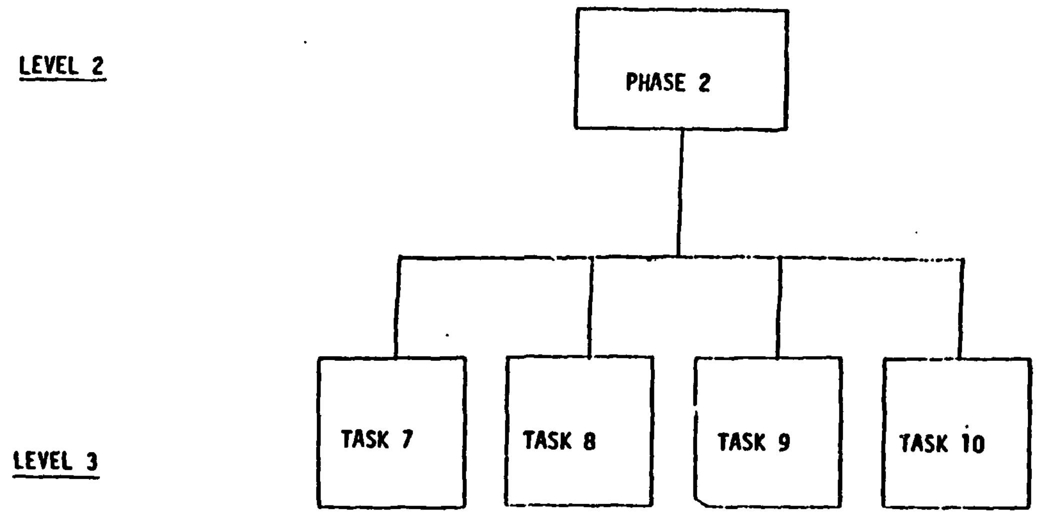
CONTRACT WORK BREAKDOWN STRUCTURE
PHASE 2



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83361581C1546

CONTRACT WORK BREAKDOWN STRUCTURE
COMMON TASKS

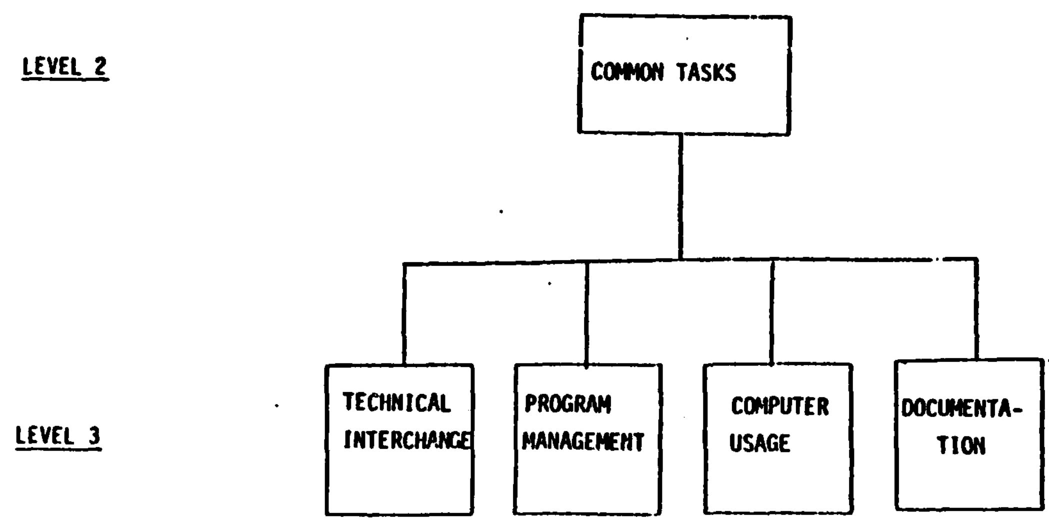

EXHIBIT C-2

SAMPLE STATEMENT OF WORK
CONTRACT F33615-82-C-1300

SECTION C

DESCRIPTION/SPECIFICATIONS

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SPACE PLATFORM FIRE CONTROL SELF DEFENSE

1.0 INTRODUCTION: The Air Force has a long term goal for utilizing space to achieve military objectives. Advances in technology are required in many areas. In particular, new and creative solutions are needed to provide a valid technology development plan for successfully implementing a space platform fire control subsystem for self defense.

2.0 SCOPE: The objective of this exploratory development effort is to define requirements, identify technology shortfalls, and scope a technology development roadmap addressing fire control aspects for self defense of a space platform.

3.0 BACKGROUND: Considerable efforts are on-going in developing a technology base for providing a viable space based weapon system. To marry the subsystem technology with the top level system design, the Avionics Laboratory has undertaken a series of requirement studies to understand the role of fire control in meeting the system requirements. Previous work has defined fire control functional requirements and assessed the capability of fire control technology to support the timeline analysis. This effort focuses on the impact to system design when the platform is required to defend itself against projected threats. Complete innovation is required if the platform is expected to survive such a threat and still perform its primary mission.

4.0 TECHNICAL REQUIREMENTS/TASKS:

4.1 General:

4.1.1 The contractor shall define requirements, identify technology shortfalls, and scope a technology roadmap addressing fire control aspects for self defense of a space platform.

4.2 Tasks:

4.2.1 Task 1 - Problem Definitions and Requirements:

4.2.1.1 The contractor shall perform a parametric trade study against current and projected threats to identify major parameters, figures of merit and the ranges of each major parameter of a self defense fire control subsystem of an autonomous spacecraft.

4.2.1.2 For the purpose of this effort, the self defense fire control subsystem shall include all that is necessary to select defensive measures in response to threats and to direct those defensive measures against the threats. The emphasis is to define those functions which must reside on the platform and which maximize survivability and mission effectiveness. Interfaces with off-platform assets shall be fully delineated.

4.2.2 Task 2 - Technical Assessment:

4.2.2.1 Using the results of Task 1, the contractor shall assess the current state-of-the-art in meeting requirements as defined by the major parameter trade study.

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4.2.2.2 The contractor shall use sensitivity analyses to identify critical issues/technology shortfalls which must be addressed to initiate development and to support development once initiated. All advances required by technology shall be expressed in terms of quantifiable operational impacts whether its mission performance, availability, or life cycle cost.

4.3.2 Task 3 - Technology Development Plan:

4.3.2.1 The contractor shall formulate a technology development plan. This plan shall include technical objectives, schedules for development including milestones and decision points, and an estimate of the magnitude of effort required, in both funding and manpower.

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EXHIBIT C-3

SAMPLE STATEMENT OF WORK
CONTRACT F33615-82-C-0629

SECTION C

DESCRIPTION/SPECIFICATIONS

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PSYCHOMOTOR INDICES OF OPERATIONAL PERFORMANCE

1.0 INTRODUCTION

1.1 The need to provide the pilot with feedback about his or her own "operational state" is as important to the successful completion of missions as is the need for providing information about the state of the aircraft. The latter is accomplished via the instrument panel and, when critical events transpire, by a warning signal about a malfunction or an impending malfunction of equipment.

1.2 The aspect of pilot "state" of concern here relates to "fatigue," which may be short-lived and indexed by "drop-outs" in psychomotor performance and in decision processes, or may be more persistent and indexed by the occurence of drowsiness. With the task demands made on today's pilot, even momentary drop-outs may be lethal. Unfortunately, one of the characteristics of "fatigue" is a diminished ability to perceive, or a reduced willingness to admit, one's malaise. It is the long-run (five to six years) intent of this effort to develop a method which will objectively predict and display such impairment so that the individual pilot may take appropriate counter measures.

1.3 The objectives of this two-year basic research project are (1) the development of preliminary equations, based on data collected during the Feasibility Study (see paragraph 3.4), which predict flying-related psychomotor performance decrements; (2) the refinement of the equations, based on data collected using laboratory dual task methodology; and (3) the planning for and establishment of a flying-related performance data acquisition system at the Crew Performance Branch (VNE), USAF School of Aerospace Medicine, Brooks AFB, TX.

2.0 SCOPE

2.1 Phases. The contractor shall execute the project in two phases: analysis of existing preliminary data (Phase 1), and system planning (Phase 2). The phases will overlap in time.

2.2 Products

2.2.1 In Phase 1, the contractor shall perform analyses of Feasibility Study data. (Attachment 1, Sequence numbers 2 and 3).

2.2.2 In Phase 2, the contractor shall suggests further investigations, including field studies. (Attachment 1, Sequence number 4).

2.2.3 It will be considered within the scope of the contract for the contractor to supply systems, equipment, and professional and technical support as needed by the government that will support the implementation of the suggested investigations of paragraph 2.2.2.

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3.0 GENERAL BRACKGROUND

3.1 The increasingly frequent occurrence of brief lapses in attention is a manifestation of aircrew fatigue. When an attentional lapse occurs concurrently with a critical change in the operational flight environment, there is high probability that the appropriate aircrew response will not occur. Characteristic and recognizable electrical patterns normally arise in the human brain and electro-oculogram (EOG) when such a lapse occurs. The electroencephalogram (EEG) and EOG have been shown to be appropriate tools, in the laboratory and in the field, for the investigation of lapse occurrence.

3.2 These observations led to the planning of a long-term research project by the Crew Performance Branch (VNE), USAF School of Aerospace Medicine. The first stage of the project called for the conduct of a feasibility study that would determine whether or not several unique laboratory capabilities could be integrated into a system in which pilot lapses could be studied.

3.3 It has been demonstrated that the state of drowsiness can be successfully predicted from complex, but readily implemented, algorithms applied to brain electrical activity. More recently, even more sophisticated investigative techniques and pattern recognition algorithms that differentiate between types of task performance anticipation, using only brain electrical activity data has been developed. Finally, it has been demonstrated that eye movement and closure measures are sensitive to time-on-task and pharmacological effects, and developed equipment and software to be used to predict performance decrements in vigilance task performance.

3.4 During a Feasibility Study, carried out with three participating laboratories under government contract, flying-related perceptual-motor performance data, brain electrical activity data, and eye movement and closure data were collected simultaneously. Three test pilots from the USAF Flight Test Center, Edwards AFB, CA, and one former USAF pilot served as subjects.

3.5 The next technical stage of the project, and one of the objectives of this contract, is to continue the analyses of data from the Feasibility Study adding an integration of the three data analysis procedures using pattern recognition and correlation approaches. The second objective of this contract is to suggest equipment for exploratory development work that will occur at the Crew Performance Branch subsequent to the end of this effort.

4.0 TECHNICAL REQUIREMENTS/TASKS. The project will be accomplished in two phases.

4.1 Phase 1, Data Analysis. The Air Force shall provide flying-related perceptual-motor performance/data. The contractor shall select several sets of tracking data for reduction using the STI Non-invasive Pilot Identification Program. The contractor shall validate the NIPIP results against the DFA results for data with and without forcing function, and demonstrate the ability of the NIPIP to measure the routine flight phases. (Attachment 1, Sequence numbers 2 and 3).

4.2 Phase 2, System Planning. The contractor shall take part in the design and characterization, in terms of performance data, of an improved task to be used for the investigation of the relationships between central nervous system electrical activity and human performance. The new task shall allow the simultaneous assessments of attention, memory, and motor skills in a presentation format that is related to the task of piloting USAF aircraft. (Attachment 1, Sequence number 4).

4.3 Also during Phase 2, the contractor shall provide to the government suggestions for further, exploratory development investigations, including the extrapolation of animal tracking performance to humans and the implications of that extrapolation for human tracking performance modeling. These investigations will be conducted by the Crew Performance Branch (VNE), USAF School of Aerospace Medicine, Brooks AFB, TX. (Attachment 1, Sequence number 4).

4.4 The contractor shall travel to and/or participate in four project workshops, convened by the government.

APPENDIX D

SAMPLE SUMMARY WORK BREAKDOWN STRUCTURE AND DEFINITIONS

APPENDIX A

SUMMARY WORK BREAKDOWN STRUCTURE AND DEFINITIONS AIRCRAFT SYSTEM

10. SCOPE

10.1 This appendix covers the summary work breakdown structure and definitions for an aircraft system.

20. REFERENCED DOCUMENTS

20.1 The following documents of the issue in effect on date of invitation for bids or requests for proposal form a part of this standard to the extent specified herein.

PUBLICATION

TD-3	Department of Defense Authorized Data List, Index of Data Item Descriptions

(Application for copies should be addressed to Naval Publications & Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, Pa 19111).

30. SUMMARY WORK BREAKDOWN STRUCTURE

30.1 Levels. The following is a summary work breakdown structure for an aircraft system:

Level 1	Level 2 (see 5.2.1.1)	Level 3 (see 5.2.1.1)
Aircraft system		
	Air vehicle	
		Airframe
		Propulsion unit
		Other propulsion
		Communications
		Navigation/guidance
		Fire control
		Penetration aids
		Reconnaissance equipment
		Automatic flight control

Level 1	Level 2(see 5.2.1.1)	Level 3 (see 5.2.1.1)
		Central integrated checkout
		Antisubmarine warfare
		Auxiliary electronics equipment
		Armament
		Weapons delivery equipment
		Auxiliary armament/weapons delivery equipment
	Training	
		Equipment
		Services
		Facilities
	Peculiar support equipment	
		Organizational/intermediate (Including equipment common to depot)
		Depot(Only)
	Systems test and evaluation	
		Development test and evaluation
		Operational test and evaluation
		Mockups
		Test and evaluation support
		Test facilities
	System/project management	
		System engineering
		Project management
	Data	
		Technical publications
		Engineering data
		Management data
		Support data
		Data depository

Level 1	Level 2(see 5.2.1.1)	Level 3 (see 5.2.1.1)
	Operational/site activation	
		Contractor technical support
		Site construction
		Site/ship/vehicle conversion
	Common support equipment	
		Organizational/intermediate (Including equipment common to depot)
		Depot (Only)
	Industrial facilities	
		Construction/conversion/expansion
		Equipment acquisition or modernization
		Maintenance
	Initial spares and initial repair parts	
		(Specify by allowance list, grouping, or hardware element)

40. DEFINITIONS

40.1 Aircraft category. Aircraft category is defined as those systems having fixed or movable wing, rotary wing, or compounded wing, manned air vehicles designed for powered or unpowered (glider) guided flight in the atmosphere.

40.2 Aircraft system. The aircraft system element refers to the complex of equipment, data, services, and facilities required to develop and produce the capability of employing those fixed or movable wing, rotary wing, or compound wing, manned air vehicles designed for powered or unpowered (glider)guided flight in the atmosphere. (Represented by A-7, C-5, E-1, UH-1D, AAFSS, XC-142, etc.)

40.2.1 Air vehicle. The air vehicle element refers to the complete flyaway, including airframe, engines, and all other installed equipment. This element includes all effort associated with the design, development, and production of complete units (prototype and operationally configured units which satisfy the requirements of their applicable specification(s), regardless of their end use). It also includes the installation and checkout of all remaining level 3 elements into the airframe to form the complete air vehicle.

40.2.1.1 Airframe. The airframe element refers to the assembled structural and aerodynamic components of the air vehicle that support subsystems essential to a particular mission. This element includes all effort outlined in 5.5.1.3 as well as the integration and assembly of all other level 3 equipments into the airframe to provide an air vehicle as a whole. It includes; for example, the basic structure (wing, empennage, fuselage, and associated manual flight control system), the air induction system, starters, exhausts, the fuel control system, inlet control system, alighting gear (tires, tubes, wheels, brakes, hydraulics, etc.), secondary power, furnishings (cargo, passenger, troop, etc), engine controls, instruments (flight, navigation, engine, etc.), environmental control, racks, mounts, intersystem cables and distribution boxes, etc., which are inherent to and nonseparable from the assembled structure, dynamic stystems, rotor group, and other equipment homogeneous to the airframe. All efforts directly related to the other level 3 elements are excluded.

40.2.1.2 Propulsion unit. The propulsion unit element refers to that portion of the air vehicle that pertains to installed engines to provide power/thrust to propel the aircraft through all phases of powered flight. This element includes the engine as a propulsion unit within itself, of reciprocating or turbo type with afterburner when appropriate; thrust reverser, thrust vector devices, transmissions, gear boxes, if furnished as in integral part of the propulsion unit; suitable for integration with the airframe. All ancilliary equipments that are not an integral part of the engine required to provide an operational primary power source (i.e., air inlets, instruments, controls, etc.) are excluded.

40-2.1.3 Other propulsion. The other propulsion element refers to that portion of the operational power/thrust source required in addition to the engine to insure the performance requirements of powered flight. This element includes; for example, propellers, booster units, thrust reversers, thrust vector devices, transmissions, and gear boxes, if not furnished as an integral part of the engine. This element excludes instruments, controls, air inlets, exhausts, starters, and other ancilliary items required for operational performance that are included in the airframe.

40.2.1.4 Communications. The communications element refers to those equipments installed in the air vehicle for communication and identification purposes. This element includes; for example, intercom, radio system(s), IFF, data link, and control boxes associated with the specific equipment. When an integrated communication, navigation, and identification package is used, it will be included here.

40.2.1.5 Navigation/guidance. The navigation/guidance element refers to those equipments installed in the air vehicle to perform the navigation/ guidance function. This element includes; for example, radar, radio or other essential navigation equipment, radar altimeter, direction finding set, doppler compass, computer, and other equipment homogeneous to the navigation/ guidance function. Panel instruments are excluded.

40.2.1.6 Fire control. The fire control element refers to that equipment installed in the air vehicle which provides the intelligence necessary for weapons delivery such as bombing, launching, and firing. This element includes; for example, radars and other sensors necessary for search rendezvous and/or tracking; self-contained navigation and air data system; displays, scopes, or sights; bombing computer and control and safety devices.

40.2.1.7 Penetration aids. The penetration aids element refers to those equipments installed in the air vehicle which assist in penetration for mission accomplishment. This element includes; for example, ferret and search receivers, warning devices and other electronic devices, electronic countermeasures, jamming transmitters, chaff, infrared jammers, terrain-following radar, and other devices homogeneous to this mission function.

40.2.1.8 Reconnaissance equipment. The reconnaissance equipment element refers to those equipments installed in the air vehicle necessary to the reconnaissance mission. This element includes; for example, photographic and electronics, infrared, and other sensors; search receivers, recorders, warning devices, magazines, and data link. Gun cameras are excluded.

40.2.1.9 Automatic flight control. The automatic flight control element refers to equipments installed in the air vehicle to provide the unpiloted automatic modes of flight path control. This element includes; for example, the automatic pilot, flight control mechanisms and connectors, mechanical and electrical parts for the signal transmission and application of power, reference sensors, stability augmentation equipment, and air data computer. Control linkages, control surfaces, or other structural parts of the airframe are excluded.

40.2.1.10 Central integrated checkout. The central integrated checkout element refers to that equipment installed in the air vehicle for malfunction detection and reporting. This element includes; for example, transducers, computer and dry tapes, recorders, displays, and stimuli.

40.2.1.11 Antisubmarine warfare. The antisubmarine warfare element refers to that equipment installed in the air vehicle peculiar to the ASW mission. This element includes, for example, sensors, computer, displays, etc.

40.2.1.12 Auxiliary electronics equipment. The auxiliary electronics equipment element refers to auxiliary or other electronics equipment not allocable to individual electronic element equipments. This element includes peculiar equipments which are not homogeneous to the prescribed electronic elements. It includes; for example, such multi-use equipments as antennae, control boxes, power supplies, environmental control, racks, mountings, etc.

40.2.1.13 Armament. The armament element refers to that equipment installed in the air vehicle to provide the fire-power functions. This element includes; for example, guns, mounts, turrets, weapon direction equipment, ammunition feed and ejection mechanisms, and gun cameras.

40.2.1.14 Weapons delivery equipment. The weapons delivery equipment element refers to that equipment installed in the air vehicle to provide the weapons delivery capability. This element includes; for example, launcher, pods, bomb racks, pylons, integral release mechanism, and other mechanical or electromechanical equipments specifically oriented to the weapons delivery function. This element excludes the bombing/navigation system which is included in fire control (40.2.1.6).

40.2.1.15 Auxiliary armament/weapons delivery equipment. The auxiliary armament/weapons delivery equipment element refers to that equipment required to provide the ancilliary functions to the applicable mission equipments. This element includes flares and ejection mechanisms, ejector cartridges, and other items homogeneous to the mission function that are not identifiable to the armament or weapons delivery elements set forth in 40.2.1.13 and 40.2.1.14.

40.2.2 Training. The training element refers to the training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will acquire sufficient concepts, skills, and aptitudes to operate and maintain the system with maximum efficiency. This element includes all effort associated with the design, development, and production of training equipment as well as the execution of training services.

40.2.2.1 Equipment. The equipment element refers to those distinctive end items of training equipment, assigned by either a contractor or military service, required to meet specific training objectives. This element includes; for example, operational trainers (i.e., simulators), maintenance trainers (i.e., MTU's), and other items such as cutaways, mockups, and models.

40.2.2.2 Services. The services element refers to services, devices, accessories, and aids necessary to accomplish the objectives of training. This element includes; for example, training plans, training aids, training course materials, contractor-conducted training including in-plant and service training, etc.

40.2.2.3 Facilities. The facilities element refers to that special construction necessary to accomplish the objectives of training. (Primarily, the brick-and-mortar-type facility constructed solely for the training mission.) The equipment used for the purpose of acquainting the trainee with the system or establishing trainee proficiency is excluded.

40.2.3 Peculiar support equipment. The peculiar support equipment element refers to those items required to support and maintain the system or portions of the system while not directly engaged in the performance of its mission, and which have application peculiar to a given defense materiel item. This element includes; for example, vehicles, equipment, tools, etc., used to refuel, service, transport, hoist, repair, overhaul, assemble, disassemble, test, inspect, or otherwise maintain the mission equipment. It also includes all effort associated with the design, development, and production of peculiar support equipment.

40.2.3.1 Organizational/intermediate. The organizational/intermediate element refers to the peculiar support equipment required to perform organizational and intermediate (field) maintenance. This equipment may also be required to perform depot maintenance, however, it is characterized by its requirement at the organizational and intermediate level of maintenance. Further breakdown may be by air vehicle subsystem (i.e., airframe, propulsion, etc.) or maintenance function (i.e., electrical maintenance and test equipment, hydraulic maintenance and test equipment, power supply equipment, handling and transportation equipment, etc.).

40.2.3.2 Depot. The depot element refers to the peculiar support equipment required to support only depot maintenance.

40.2.4 Systems test and evaluation. The systems test and evaluation element refers to the use of prototype, production, or specially fabricated hardware to obtain or validate engineering data on the performance of the aircraft system. This element includes the detailed planning, conduct, support, data reduction and reports from such testing, and all hardware items which

are consumed or planned to be consumed in the conduct of such testing. It also includes all effort associated with the design and production of models, specimens, fixtures, and instrumentation in support of the test program. Test articles which are complete units (i.e., functionally configured as required by the aircraft equipment) are excluded. Development component acceptance, etc., testing which can be specifically associated with the hardware element, unless these tests are of special contractual or engineering significance (e.g., associate contractor), are also excluded.

40.2.4.1 Development test and evaluation. The development test and evaluation (DT&E) element refers to that test and evaluation conducted to: (a) demonstrate that the engineering design and development process is complete; (b) demonstrate that the design risks have been minimized; (c) demonstrate that the system will meet specifications; (d) estimate the system's military utility when introduced; (e) determine whether the engineering design is supportable (practical, maintainable, safe, etc.), for operational use, and (f) provide test data with which to examine and evaluate tradeoffs against specification requirements, life cycle cost, and schedule. DT&E is planned, conducted and monitored by the developing agency of the DOD component. It includes; for example, such models and tests as wind tunnel, static, drop, and fatigue; integration ground tests, engine military qualification tests (MQT), preliminary flight rating tests (PFRT), test bed aircraft and associated support; development flight test, test instrumentation, test equipment (including its support equipment), chase aircraft and support thereto, etc.

40.2.4.2 Operational test and evaluation. The operational test and evaluation element refers to that test and evaluation conducted by agencies other than the developing command to assess the prospective systems's military utility, operational effectiveness, operational suitability, logistics supportability (including compatibility, interoperability, reliability, maintainability, logistic requirements, etc.), cost of ownership, and need for any modifications. Initial operational test and evaluation (IOT&E) conducted during the development of a weapon system will be included in this element. This element encompasses such tests as flight tests, sea trials, etc., and support thereto, required to prove the operational capability of the deliverable system. It also includes contractor support (e.g., technical assistance, maintenance, labor, material, etc.) consumed during this phase of testing.

40.2.4.3 Mockups. The mockups element refers to the design engineering and production of system or subsystem mockups which have special contractual or engineering significance, or which are not required solely for the conduct of one of the above elements of testing.

40.2.4.4 Test and evaluation support. The test and evaluation support element refers to all support elements necessary to operate and maintain systems and subsystems during flight test and evaluation which are not consumed during the flight-testing phase and other support requirements that are not allotable to a specific phase of testing. This element includes; for example, reparable spares, repair of reparables, repair parts, contractor technical support, etc., not allocable to preceding test and evaluation elements. Operational and maintenance personnel, consumables, special fixtures, special instrumentation, etc., which are utilized and/ or consumed in a single element of testing and which should, therefore, be included under that element of testing are excluded.

40.2.4.5 Test facilities. The test facilities element refers to those special test facilities required for performance of the various developmental tests necessary to prove the design and reliability of the system or subsystem. This element includes; for example, engine test fixtures, white rooms, test chambers, etc. The brick-and-mortar-type facilities allocable to industrial facilities are excluded.

40.2.5 System/project management. The system/project management element refers to the systems engineering and technical control as well as the business management of particular systems/projects. This element encompasses the planning, directing, and controlling the definition, development, and production of a system/project including the functions of logistics and logistics support, maintenance support, facilities, personnel and training, testing, and activation of a system. System/ project management effort than can be associated specifically with the hardware element is excluded, unless this management effort is of special contractual or engineering significance (e.g., associate contractor).

40.2.5.1 System engineering. The system engineering element refers to the technical and management efforts of directing and controlling a totally integrated engineering effort of a system program. This element encompasses the system engineering effort to define the system and the integrated planning and control of the technical program efforts of design engineering, logistics engineering, specialty engineering, production engineering, and integrated test planning. This element includes but is not limited to: the system engineering effort to transform an operational need or statement of deficiency into a description of system requirements and a preferred system configuration; the logistics engineering effort to define, optimize and integrate the logistics support considerations into the mainstream engineering effort to insure the development and

production of a supportable and cost effective weapon system; and the technical planning and control effort for planning, monitoring, measuring, evaluating, directing and replanning the management of the technical program. It excludes the actual design engineering, and production engineering directly related to the products or services of a deliverable end item. Examples of system engineering efforts include:

a. System definition, overall system design, design integrity analysis, system optimization, system/cost effectiveness analysis, and intrasystem and intersystem compatibility assurance, etc., the integration and balancing of reliability, maintainability, producibility, safety, and survivability; human factors, personnel and training program requirements, security requirements, configuration identification and control, quality assurance program, value engineering, preparation of equipment and component performance specifications, design of test and demonstration plans;

b. Support synthesis, design impact projections, life cycle cost factors, time factors, tradeoff analysis, logistics design appraisal, use studies, support function requirements identification, repair level determination, task analysis, standardization review, logistics requirements identification, logistics support verification, and the preparation and updating of the logistics support plan, the maintenance plan, facilities planning (operational and maintenance), the transportation and handling plan, etc., and;

c. Preparation of the Systems Engineering Mangement Plan (SEMP), specification tree, program risk analysis, system test planning, decision control process, technical performance measurement, technical reviews, subcontractor/vendor reviews, work authorization, technical documentation control, etc.

40.2.5.2 Project management. The project management element refers to the business and administrative planning, organizing, directing, coordinating, controlling, and approval actions designated to accomplish overall project objectives which are not associated with specific hardware elements and are not included in system engineering. Examples of these activities are logistics management, cost/schedule/performance measurement, contract management, data management, vendor liaison, contract WBS, etc.

40.2.6 Data. The data element refers to all deliverable data required to be listed on a DD Form 1423. The data requirements will be selected from TD-3. This element includes only such effort that can be reduced or will not be incurred if the data item is eliminated. If the data are government peculiar, include the efforts for acquiring, writing, assembling, reproduction, packaging and shipping. It also includes the effort for repreparing into government format with reproduction and shipment if data are identical to that used by the contractor, but in a different format.

40.2.6.1 Technical publications. The technical publications element refers to those formal technical orders/manuals developed, as well as commercial, advance, real property installed equipment, and miscellaneous manuals for the installation, operation, maintenance, overhaul, training and reference of hardware, hardware systems and computer programs; and contractor instructional materials, inspection documentation, and historical type records that may accompany individual items of equipment. This element includes the data item descriptions set forth in functional category M of TD-3.

40.2.6.2 Engineering data. The engineering data element refers to those engineering drawings, associated lists, specifications, and other documentation required by the government in accordance with functional categories E, H, R, S, and T of TD-3. This element includes; for example, all plans, procedures, reports, and documentation pertaining to systems, subsystems, computer programs, component engineering, testing, human factors, analysis, etc.

40.2.6.3 Management data. The management data element refers to those data items necessary for configuration management, cost, schedule, contractual data management, programs management, etc., required by the government in accordance with functional categories A, F, and P of TD-3. This element includes; for example, contractor cost reports, cost performance reports, contractor fund status reports, and schedule, milestone, networks, integrated support plans, etc.

40.2.6.4 Support data. The support data element refers to those data items designed to document the logistics support planning and provisioning process in accordance with functional categories L and V of TD-3. This element includes; for example, supply and general maintenance plans and reports, transportation, handling, packaging information, etc.; and data to support the provisioning process.

40.2.6.5 Data depository. The data depository element refers to a facility designated to act as custodian in establishing and maintaining a master engineering specification and drawing depository service for government-approved documents that are the property of the U.S. Government. As custodian for the government, the contractor is authorized by approved change orders to maintain these master documents at the latest approved revision level. When documentation is called for on a given item of data retained in the depository, the charges (if charged direct) will be to the appropriate data element. This element represents a distinct entity of its own and includes all effort of drafting, clerical, filing, etc., required to provide the service outlined above. All similar efforts for the contractor's internal specification/drawing control system in support of his engineering/production activities are excluded.

40.2.7 Operational/site activation. The operational/site activation element refers to to the real estate, construction, conversion, utilities, and equipment to provide all facilities required to house, service, and launch prime mission equipment at the organizational and intermediate level. This element includes conversion of site, ship, or vehicle; system assembly, checkout, and installation into site facility or ship to achieve operational status. It also includes contractor support in relation to operational/site activation.

40.2.7.1 Contractor technical support. The contractor technical support element refers to all materials and services provided by the contractor related to activation. This element includes; for example, repair of reparables, standby services, final turnover, etc.

40.2.7.2 Site construction. The site construction element refers to the real estate, site preparation, construction, and other special-purpose facilities necessary to achieve system operational status. This element includes the construction of utilities, roads, and interconnecting cabling.

40.2.7.3 Site/ship/vehicle conversion. The site/ship/vehicle conversion element refers to all materials and services required to provide for the conversion of existing sites or ships to accommodate the mission equipment and selected support equipment directly related to the specific system. This element includes launch, operating, support, and other conversion necessary to achieve system operational status. Where appropriate, specify by site or ship.

40.2.8 Common support equipment. The common support equipment element refers to those items required to support and maintain the system or portions of the system while not directly engaged in the performance of its mission, and which are presently in the DOD inventory for support of other systems. This element includes all efforts required to assure the availability of this equipment for support of the particular defense materiel item. It also includes the acquisition of additional quantities of those equipments if caused by the introduction of the defense materiel item into operational service.

40.2.8.1 Organizational/intermediate. The organizational/intermediate element refers to the common support equipment required to perform organizational and intermediate (field) maintenance. This equipment may also be required to perform depot maintenance, however, it is characterized by its requirement at the organizational and intermediate level of maintenance. Further breakdown may be by air vehicle subsystem (i.e., airframe, propulsion, etc.), or maintenance function (i.e., electrical maintenance and test equipment, hydraulic maintenance and test equipment, power supply equipment, handling and transportation equipment, etc.).

4.2.8.2 Depot. The depot element refers to the common support equipment required to support only depot maintenance.

40.2.9 Industrial facilities. The industrial facilities element refers to the construction, conversion, or expansion of facilities for production, inventory, and contractor depot maintenance required by one or more suppliers for the specific system. This element includes; for example, equipment acquisition, or modernization, where applicable, and maintenance of the above facilities or equipment.

40.2.9.1 Construction/conversion/expansion. The construction/conversion/expansion element refers to the real estate and preparation of system peculiar facilities for production, inventory, depot maintenance, and other related activities.

40.2.9.2 Equipment acquisition or modernization. The equipment acquisition or modernization element refers to production equipment acquisition, modernization, or transferal of equipment for the particular system. (Pertains primarily to government owned and leased equipment under facilities contract.)

40.2.9.3 Maintenance (industrial facilities). The maintenance (industrial facilities) element refers to the maintenance, preservation, and repair of industrial facilities and equipment.

40.2.10 Initial spares and initial repair parts. The initial spares and initial repair parts element refers to the spare components or assemblies used for replacement purposes in end items of equipment. This element excludes development test spares, and spares provided specifically for use during system installation, assembly, and checkout on site.

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